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Thermal and Intake Studies -
Guidance Manual

Michigan Water Resources Commission
Bureau of Water Management
Michigan Department of Natural Resources

February 1975

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Guidance Manual

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THERMAL AND INTAKE STUDY GUIDANCE MANUAL

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CHAPTER I

INTRODUCTION

On October 18, 1972, the United States Congress enacted the Federal Water Pollution Control Act Amendments of 1972, also known as Public Law 92-500. This Act requires that those municipalities and industries that have discharges to the surface waters of the United States must obtain a National Pollutant Discharge Elimination System (NPDES) Permit either from the U.S. Environmental Protection Agency or an authorized State agency. On October 17, 1973, the State of Michigan, Michigan Water Resources Commission, became authorized to issue and enforce NPDES Permits.

The Act requires that NPDES Permits be evaluated using both the U. S. Environmental Protection Agency promulgated effluent guideline limitations and the State's Water Quality Standards and that the limits imposed shall be the more stringent limitations of the two determinations. On October 8, 1974, the U.S. EPA promulgated effluent guidelines and standards for the Steam Electric Power Generating Point Source Category were published in the Federal Register. The earlier proposed guidelines required close-cycle cooling of all power plants. However, the promulgated guidelines provided for exemptions based on age and size. Units placed into operation prior to January 1, 1970, are not required to meet the limitations on the discharge of heat. Of the units placed into operation between January 1, 1970, and January 1, 1974, only the largest base load units (that is, those of 500 megawatts capacity or greater) will be subject to heat limitations (see Federal Register, Volume 39, Number 196, Tuesday, October 8, 1974, Page 36188). Regardless of the size of unit or the date placed in operation, if the thermal component of the discharge violates Michigan's Water Quality Standards, then thermal restrictions must be placed on the discharge.

Section 316(a) of Public Law 92-500 states if an effluent limitation is proposed for the control of the thermal component of the discharge and the permittee can demonstrate to the State of Michigan that the required thermal effluent limitations are more stringent than necessary to assure the protection and propagation of a balanced indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is to be made, the State may impose less stringent requirements.

In addition to the Chapter II Section of this Guidance Manual which deals with the thermal component of the discharge, Chapter III addresses Section 316(b) of the Act. This Section requires that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. All power plants must perform 316(b) intake studies.

When both a 316(a) and (b) demonstration are required, they will be reviewed at the same time to determine their inter-relationship.

The study plans and final reports, etc., are specific requirements of each NPDES Permit and the permit should be referred to for compliance dates.

Decisions on cooling water use will be made on a waterbody-wide assessment of total aquatic ecosystem effects, case by case for each facility and case by case for each waterbody, considering the cumulative effects. The Director may determine that operation of a single facility will assure the protection and propagation of a balanced, indigenous community in the waterbody or segment thereof. However, he must take into account the combined and cumulative effects of other facilities using the waterbody or segment thereof for cooling water and/or discharge. This philosophy of consideration of waterbody-wide effects is expressed in Chapter IX of the 316(a) guidance on Thermal Load Analysis, in Appendix A of that document on Biological Value System for Establishing Mixing Zones, and in the 316(b) Guidance. Therefore the Director may allocate use of the waterbody or segment thereof based on physical or biological effects as means of limiting both individual or combined thermal loads, intake volumes, or mixing zone size. In the case of water bodies or segments thereof which are common to other states and/or Canada, the Director may consult with responsible regulatory authorities of those governments.

Representative, Important Species

In the rules governing Section 316(a) of P.L. 92-500 and the 316(a) Guidance, three types of demonstrations are provided for: 1. Absence of Prior Appreciable Harm; 2. Protection of Representative Important Species; and 3. Biological, Engineering and Other Data. Types 1 and 2 call for listing of aquatic life and wildlife in various zones in the plant vicinity and such a listing is logically a part of a Type 3 demonstration. The Type 2 focuses on assurance of protection and propagation of representative, important species. The 316(a) regulations instruct the Director to establish representative, important species. The staff of the Water Resources Commission, working with the Fisheries Division of the Department of Natural Resources, and in consultation with the U. S. Fish and Wildlife Service, prepared a list, dated July 25, 1974, which was approved by the Director.

The list, which is incorporated into the guidance package as Chapter IV, can be used by applicants in two ways: as guidance to species which should be considered in any type of demonstration and as the representative, important species in a Type 2 demonstration. The fish species are also appropriate for consideration in intake entrainment and entrapment studies.

Staff identified important species as those which are:

(a) commercially or recreationally valuable; (b) rare, threatened or endangered; (c) important to the well-being of species in (a) or (b); (d) are nuisance or potential nuisance organisms, or (e) are critical to the structure and function of the ecological system. To facilitate identification of these organisms staff established eight zones throughout the state whose physical, chemical and biological characteristics were similar enough so that generalizations could be made regarding their ecosystem structure. (Table 1 and Figure 1 of Chapter IV.) The representative, important species and species categories for selected trophic levels are identified in Tables 2 through 15 of Chapter IV. Because the biota is variable in the warmwater inland situations which receive thermal discharges, a species list was prepared for certain individual sites within the category Zone 9, inland warmwater locations and anadromous migratory routes.

Because of site-specific differences, the list for each zone cannot be considered exclusive, nor can it be concluded that all species listed need be considered at each site. The Director, in recognizing the study plan of the applicant, will judge what species should be considered as representative, important species after consultation with the applicant.

Critical Questions

Notwithstanding an applicant's 316(a) or (b) demonstration or study relative to ecosystem effects of plant operation, the Director will consider how adequately the applicant has addressed the following questions: (if they are applicable to the type of presentation being made):

1. Are the temporal, spatial, thermal and volumetric characteristics of the buoyant plume known or adequately predicted?
2. Are the temporal, spatial, thermal and volumetric characteristics of the sinking plume known or adequately predicted?
3. Are the volume, velocity, time of passage and time-temperature information in the intake facilities, through the plant, in the discharge facilities and in the centerline of the thermal plume established or adequately predicted?
4. Are the seasonal phytoplankton populations by number and species known sufficiently well to detect possible changes in the receiving waterbody?
5. Are the seasonal phytoplankton populations by number and species known sufficiently well to detect possible changes in the discharge area and adjacent waters?

6. Relative to phytoplankton of the discharge area, adjacent waters and the receiving waterbody, is it known or predicted what portions of the populations are exposed to stresses caused by plant operation?
7. Are the effects of such exposures on phytoplankton populations known or predicted (impairment or stimulation of productivity, time-temperature tolerances, population shifts both local and waterbody-wide, etc.)?
8. Are questions 4-7 addressed relative to zooplankton?
9. Are the seasonal populations of benthic and attached algae in the discharge area and adjacent waters known sufficiently well to detect possible changes?
10. Are effects of the plant operation on populations of benthic and attached algae considered, known or predicted?
11. Are the macroinvertebrate populations in the discharge area and adjacent waters known sufficiently well to detect possible changes?
12. Are effects of plant operation on macroinvertebrate populations considered, known or predicted?
13. Are the aquatic macrophyte populations in the discharge area and adjacent waters known sufficiently well to detect possible changes?
14. Are effects of plant operation on aquatic macrophyte populations considered, known or predicted?
15. Is the seasonal abundance of fish eggs and larvae by species known sufficiently well to detect possible changes in the discharge area and adjacent waters?
16. Is it known or predicted what portions of the populations of fish eggs and larvae are exposed to stresses caused by plant operation?
17. Are the effects of such exposures on fish eggs and larvae considered, known or predicted?
18. Is it known or predicted what impact such effects will have on fish populations in the discharge area, adjacent waters and the receiving waterbody?
19. Are the seasonal abundance and habits of adult fish by species known sufficiently well to detect possible changes in the discharge area and adjacent waters?
20. Is it considered, known or predicted what effect operation of the facility has or will have on these fish and their activities?
21. Have the waterbody-wide effects of preparation of this plant been adequately explored? In conjunction with other facilities using cooling water?

CHAPTER II

DRAFT

FOR
316(a) TECHNICAL GUIDANCE ~~+~~ THERMAL DISCHARGES DEMONSTRATIONS

September 30, 1974

Water Planning Division
Office of Water and Hazardous Materials
Environmental Protection Agency

AS MODIFIED FOR USE BY THE
MICHIGAN WATER RESOURCES COMMISSION
JANUARY, 1975

~~DRAFT~~

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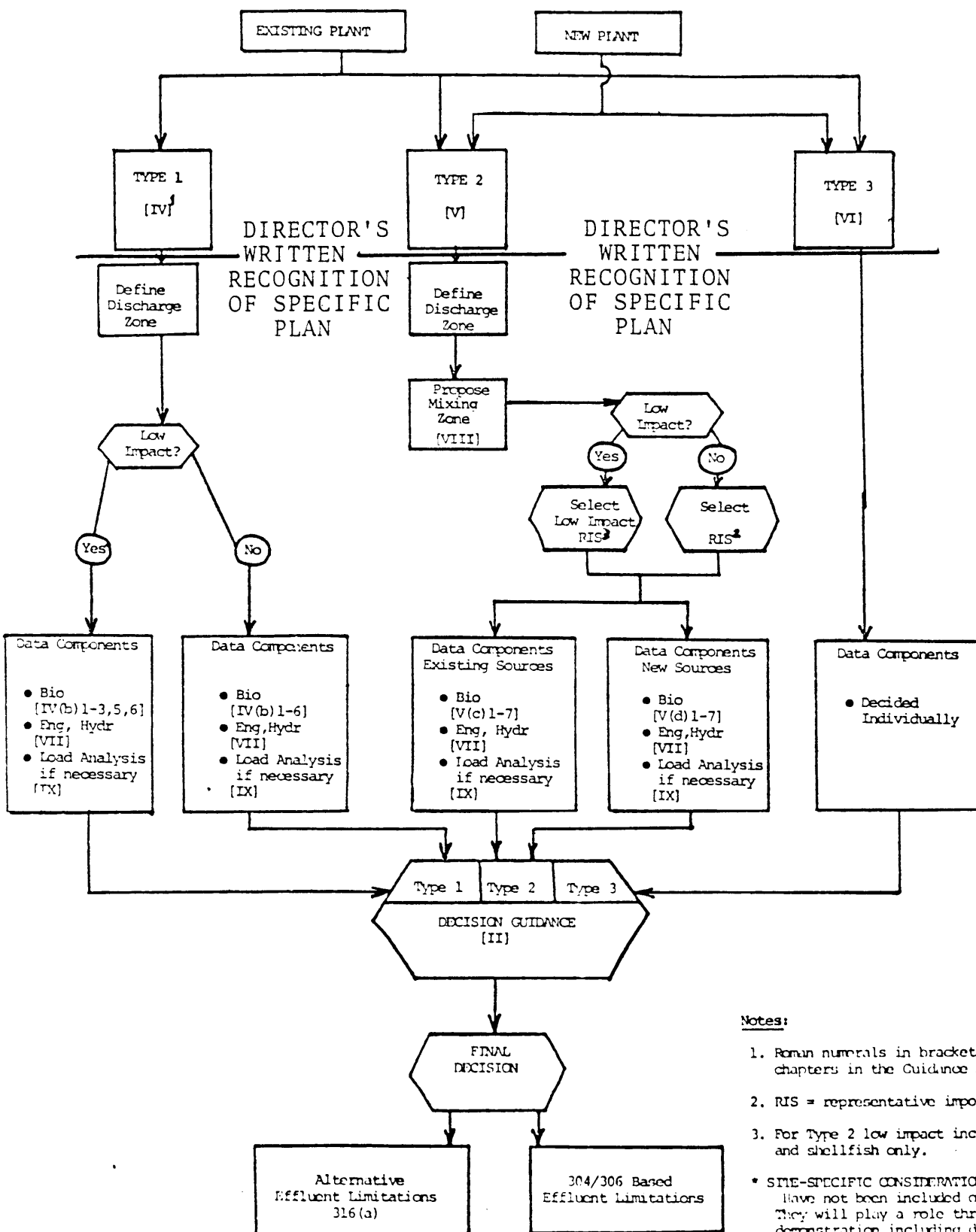
INTRODUCTION(a) Foreword.

This guidance manual describes the information which should be developed and evaluated in connection with the possible modification, pursuant to section 316(a) of the Federal Water Pollution Control Act, as amended, 33 USC 1251, 1326(a), and 40 CFR Part 122, of any effluent limitation proposed for the control of the thermal component of any discharge otherwise subject to the provisions of section 301 or 306 of the Act. It is intended for use by ~~EPA and State water quality agencies in establishing or reviewing proposed thermal effluent limitations;~~ by owners or operators of point sources who may file applications under section 316(a) and by members of the public who may wish to participate in any 316(a) determination.

Three types of demonstration are defined--Absence of Prior Appreciable Harm (Type 1), Protection of Representative, Important Species (Type 2) and Biological, Engineering and Other Data (Type 3) (see 316(a) Information Flow Chart, below). Where preparation of a demonstration will require a significant period of time after application has been made for a permit to include alternative effluent limitations, a plan of study and demonstration should be established, with the advice and consultation of the ~~Regional Administrator (or Director).~~^{1/} (See 40 CFR ~~§122.5 (or~~ §122.11).^{2/}

1. Throughout these guidelines the phrase "~~Regional Administrator (or~~ Director)" means the relevant permitting authority, unless the context requires otherwise. THE RELEVANT PERMITTING AUTHORITY IS THE CHIEF ADMINISTRATIVE OFFICER OF THE MICHIGAN WATER RESOURCES COMMISSION, EXECUTIVE SECRETARY RALPH W. PURDY.

316(a) INFORMATION FLOW CHART*



Notes:

1. Roman numerals in brackets refer to chapters in the Guidance Manual.
 2. RIS = representative important species
 3. For Type 2 low impact includes fish and shellfish only.
- * **SITE-SPECIFIC CONSIDERATIONS:**
Have not been included on the chart. They will play a role throughout any demonstration including definition of a mixing zone, selection of RIS, and changes, if any, in data components.

Each Informational Item identified in this guidance for the selected type(s) should be included in full in the demonstration unless the **RECOGNIZED BY THE DIRECTOR** established plan/provides otherwise.

(b) Legal Requirements.

Heat discharged into water is a pollutant. (Section 502(6), FWPC Act.) Point source dischargers of pollutants must achieve, not later than July 1, 1977, effluent limitations based on the best practicable control technology currently available ("BPCTCA") or any more stringent limitation required by certain State or Federal laws or regulations, including applicable water quality standards; and they must further achieve, not later than July 1, 1983, effluent limitations based on the best available technology economically achievable ("BATEA"). (Section 301.) The Administrator* is required to publish regulations to define BPCTCA for classes and categories of point sources (section 304(b)) and establish Federal standards of performance for new sources within certain categories of sources. (Section 306.)

Effluent limitations guidelines under section 304(b) and new source standards of performance under section 306 include limitations on heat for those industries for which such limitations are appropriate. ~~Effluent Limitations~~ Guidelines and Standards, Steam Electric Power Generating Point Source Category (40 C.F.R. Part 423), include such limitations. **

*"ADMINISTRATOR" MEANS THE ADMINISTRATOR OF THE U. S. ENVIRONMENTAL PROTECTION AGENCY.

**SEE FEDERAL REGISTER, VOL. 39, NO. 196, PGS. 36186-36207, OCT. 8, 1974.

Effluent limitations proposed pursuant to section 301 or 306 for the thermal component of a discharge may be modified or waived if the owner or operator of the source is able to demonstrate that the effluent limitations proposed for the thermal component of the discharge are more stringent than necessary to protect the balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which

the discharge is made.^{2/} A DETERMINATION AND/OR BIOLOGICAL AND

evaluation of the water quality impact of the individual discharge. THERMAL COMPONENT OF THE DISCHARGE FROM THE FACILITY (TAKING INTO ACCOUNT THE INTERACTION OF THE THERMAL COMPONENT WITH OTHER POLLUTANTS). A FURTHER FACTOR INFLUENCING THE BASIS FOR DETERMINATION MAY BE AN EVALUATION OF INFORMATION RELATIVE TO EC. 316(b).* THE DIRECTOR WILL ALSO CONSIDER THE COMBINED EFFECTS OF OTHER WASTEWATER DISCHARGES AND COOLING WATER USES ON THE WATERBODY OR WATERBODY SEGMENT.

2. Section 316(a) provides:

"With respect to any point source otherwise subject to the provisions of section 301 or section 306 of this Act, whenever the owner or operator of any such source, after opportunity for public hearing, can demonstrate to the satisfaction of the Administrator (or, if appropriate, the State) that any effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made, the Administrator (or, if appropriate, the State) may impose an effluent limitation under such sections for such plant, with respect to the thermal component of such discharge (taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on that body of water."

Regulations describing requirements under section 316(a) should be consulted in connection with any 316(a) presentation. (See 40 C.F.R. Part 122.)**

SEE 40 C.F.R. PART 122, SEC. 122.16(b) AND MICHIGAN GUIDELINES FOR 316(b). RESPONSE OF EPA TO COMMENTS ON PROPOSED THERMAL REGULATIONS STATES, "IN MANY INSTANCES THE DETERMINATION WITH RESPECT TO SECTION 316(a) SHOULD BE MADE IN CONJUNCTION WITH THE DETERMINATION REQUIRED BY VIRTUE OF SECTION 316(b)". SEE "THERMAL DISCHARGES", FEDERAL REGISTER, VOL. 39, No. 196, PG. 36184, THIRD COLUMN, ITEM 11, OCTOBER 8, 1974.)

IBID, PGS. 36176-36184.

(c) Applicant's Demonstration.

An applicant, after consultation with the Regional Administrator-
- (for Director), may present evidence addressing any one or more appropriate
demonstration types. All demonstrations should be completed within a
time frame which will assure maximum progress towards compliance with
the statutory deadlines of sections 301 and 306.

Each demonstration item set forth in Chapters IV-VI for the subject
demonstration type will normally apply. The Regional Administrator (or
Director) may authorize or request an applicant to modify, reduce,
expand or eliminate any item as warranted by the circumstances of the
particular case. / The advance/concurrence or nonconcurrence of the
Regional Administrator (or Director) in a particular demonstration
AND ARE PART OF THE MICHIGAN DEMONSTRATION PROCEDURE.
should help all parties identify a relevant showing. However, the
statutory burden of proof for alternative effluent limitations is on the
applicant. Therefore, any advance agreement should not be taken as
reducing the applicant's responsibilities, nor should any disagreement
be allowed to prejudice the conclusion.

Any alternative effluent limitation imposed pursuant to section
316(a) must assure the protection and propagation of a balanced, indige-
ASSURANCE WILL BE JUDGED ON THE EVIDENCE AND SCIENTIFIC ADEQUACY OF THE DEMON-
nous community of shellfish, fish and wildlife. / Therefore, the applicant STRATIC
submitting evidence for a 316(a) evaluation should submit information on
all modes of discharge that he may be contemplating. For example, if
his information indicates that a closed system requirement is too stringent

but does not justify the use of a simple once through discharge, then he should have sufficient evidence to justify some other mode of discharge (a diffuser or a "helper" cooling tower). This is imperative* since time may not allow for another long-term 316(a) study (due to BPCTCA and BATEA deadlines). If this is the case and if there is not enough evidence to assure protection of the balanced, indigenous community in using another discharge cooling system, then there may be no other choice but to require a closed cycle cooling system.

Since by law the burden of proof in any 316(a) demonstration is on the applicant, effluent limitations proposed pursuant to sections 301 or 306 will not be modified if the weight of the evidence indicates that such limitations are not unnecessarily stringent. Neither will they be modified where the evidence is insufficient to allow the Regional Administrator-(or Director) to determine whether they are unnecessarily stringent or not. Modification will be granted only where the applicant succeeds in making a demonstration which (1) affirmatively shows that the proposed limitations are more stringent than necessary and (2) is not outweighed by any evidence to the contrary.

THE DIRECTOR MAY DETERMINE THAT THE THERMAL COMPONENT OF THE DISCHARGE FROM AN EXISTING OR PLANNED SOURCE WILL ASSURE THE PROTECTION AND PROPAGATION OF A BALANCED INDIGENOUS COMMUNITY OR THAT SUCH DISCHARGE FROM AN EXISTING SOURCE HAS NOT CAUSED PRIOR APPRECIABLE HARM. HOWEVER, INTAKE AND IN-PLANT BIOLOGICAL EFFECTS ARE RELATED TO THE THERMAL COMPONENT OF THE DISCHARGE BECAUSE THE THERMAL COMPONENT DEPENDS ON THE AMOUNT OF COOLING WATER USED. SECTION 316(b) CONCERNS TECHNOLOGY REQUIREMENTS FOR COOLING WATER INTAKES TO MINIMIZE ADVERSE ENVIRONMENTAL IMPACT. IN REACHING A DECISION ON 316(a) OR (b) THE DIRECTOR MAY WISH TO CONSIDER ALL EVIDENCE ON BOTH ASPECTS OF COOLING WATER USE.

(d) Format of Demonstration

Each demonstration should include the following:

1. Pagination.
2. A DETAILED table of contents.
3. Supportive reports, documents and raw data which are not from the open scientific literature.

*IF AN APPLICANT CHOOSES NOT TO SUBMIT ALTERNATIVE MODES OF DISCHARGE TOGETHER WITH RELATED ENVIRONMENTAL IMPACT INFORMATION, HE MAY BE VULNERABLE TO COMMISSION AND EPA PRESSURE CONSIDERING BPCTCA AND BATEA DEADLINES.

4. Bibliographic citations to page number.

5. An interpretive, comprehensive narrative summary of the demon-

stration, , WHICH WILL SERVE, IN PART, AS THE BASIS FOR THE
DIRECTOR'S DECISION. AND MAY INCLUDE TABLES AND FIGURES.

The summary should include a table of contents/. Sources of data

used in the summary should be cited to page number. The summary should include a clear discussion stating why the applicant's demonstration is sufficient to assure that the proposed discharge will assure the protection and propagation of a balanced, indigenous community.

(e) Application.

The following points may be helpful in the review and application of these guidelines.

1. How is the Manual to be used: Are its requirements binding?

A. The guidance should normally be followed for each demonstration. However, specific demonstration items can be changed to fit the circumstances of the particular case, with the advice and consultation of the Regional Administrator (or Director). (SEE FLOW CHART, PG. 2)
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to develop its plan of study and demonstration promptly, in accordance with the law's time constraints. Of course, a demonstration plan cannot be binding on either the applicant or the Regional Administrator (or Director), in view of the possibility that developing information may suggest changes in the study; the potential for third party involvement or judicial review; and the law's mandate that the burden of proof under section 316(a) is on the applicant.

2. How should the right demonstration type be selected? Is there any screening procedure?

A. No formal screening mechanism can adequately predict the "right" demonstration type for each applicant. The applicant should select ~~his~~ ^{THE} proposed demonstration type or types through consideration of this guidance, the nature of ~~its~~ ^{THE} discharge (existing or new; low impact or other, etc.) and the availability or attainability of information. Consultation with the ~~Regional Administrator (or Director)~~ is also encouraged.

3. How comprehensive must a demonstration be in order to provide the required assurance of protection and propagation?

A. The study must provide reasonable assurance of protection and propagation of the indigenous community. Mathematical certainty regarding a dynamic biological situation is impossible to achieve, particularly where desirable information is not obtainable. Accordingly, the ~~Regional Administrator (or Director)~~ must make decisions on the basis of the best information reasonably attainable. At the same time, if he finds that the deficiencies in information are so critical as to preclude reasonable assurance, then alternative effluent limitations should be denied. It is expected in any case that after publication of this guidance potential applicants will conduct monitoring and data collection activities responsive to the applicable portions of this document. In that way, as initial permits come up for renewal, subsequent 316(a) judgments may be made with increasing levels of confidence, and new effluent limitations may be imposed as necessary (except as provided in section 316(c)).

4. Will there be enough time to prepare the demonstrations called for by the guidelines?

A. The statutory timetables are very tight, and the 316(a) statutory test may require preparation of rather extensive information in order to reach a reasonable conclusion. The time needed for individual demonstrations will vary according to the demonstration type being undertaken and the data which the applicant has already collected. No applicant should lack existing useful data on its own discharge or proposed discharge. Where a demonstration cannot be completed prior to the date for issuance of a permit, a permit may be issued for a term of up to five years which requires the source to achieve the initially proposed effluent limitations no later than the date specified by applicable law, regulations and standards, but the permittee may be afforded an opportunity to request a hearing after additional information has been developed. (See 40 C.F.R. §§122.10(b), 122.15(b).)

5. Shouldn't a showing of compliance or noncompliance with applicable water quality standards be conclusive?

A. The statutory test established by section 316(a) is distinct from the multiple statutory objectives of water quality standards. In addition, standards may fail to address site-specific issues, such as refined temperature limits to protect spawning areas or to reflect a community which has become adapted to natural local conditions. Therefore, compliance or noncompliance with standards alone is not a sufficient demonstration. The law indicates that standards should be modified

where necessary to make them consistent with section 316(a) decisions. Where such modifications have taken place, or wherever the standards are fully consistent with the 1983 goals of the Act (see section 101(a)(2)), compliance or noncompliance with standards may be a persuasive factor in the 316(a) evaluation.

6. Can the outcome of a proposed demonstration be predicted, so that the applicant can commence any needed planning and construction?

A. Each demonstration involves a distinct case and a distinct water body situation. Firm decision rules would be arbitrary, and their application would fail to provide against excessive environmental risk or unnecessarily stringent outcomes. Instead of firm rules, therefore, the guidelines set forth for each demonstration type a series of factors the presence of which would tend to indicate that section 316(a) relief should not be granted. These non-binding guidelines should be useful to show the types of considerations which may be determinative.

7. Does completion of a satisfactory 316(a) demonstration respecting the thermal component of its discharge assure the applicant of relief from the requirements of sections 301 and 306?

A. No. All impacts of the plant must be analyzed and weighed. Section 316(a) requires consideration of the interaction of the thermal component of the discharge with other pollutants, such as chemicals or the thermal discharges of other sources. In addition to considerations

under section 316(a), other possible harmful effects of the plant's operation and discharge must be prevented, including any excessive impact on water resources or harmful effects caused by the intake structure and/or entrainment. (See section 316(b) of the Act and 40 C.F.R. Parts 401, 402.) Guidance on entrainment will be forthcoming.

DECISION GUIDANCE

This chapter provides guidance for section 316(a) decisions by listing factors which suggest a failure to assure the protection and propagation of the balanced, indigenous community. These factors should be used solely as guidance, not as specific decision criteria for denial of alternative effluent limitations. The weight given to particular factors will differ regionally in accordance with emphasis on specific regional problems. Additional factors may also be considered.

NOTE: The factors set forth in this chapter relate solely to the thermal impact of the applicant's discharge. A permit may be issued only if the plant's operation and discharge will meet all applicable requirements of law, including restrictions on intake and entrainment effects and the chemical component of the discharge. Guidance on entrainment will be forthcoming.

1. Type I: Absence of Prior Appreciable Harm.

A failure to demonstrate the absence of prior appreciable harm may be suggested by any of the following:

(a) Evidence of damage to the balanced, indigenous community, or community components, resulting in such phenomena as those identified in the definition of appreciable harm. (See Chapter III, paragraph (10).)

(b) Absence of a convincing and otherwise satisfactory rationale where needed to explain any information submitted by the applicant. (See Chapter IV, paragraphs (b)(1)-(6).)

(c) Failure to provide sufficient information to form the basis for a determination.

(d) Any other evidence that the protection and propagation of the balanced, indigenous community is not being assured.

2. Type 2: Protection of Representative, Important Species.

A failure to demonstrate that the discharge (existing or proposed) is consistent with assurance of the protection and propagation of representative, important species may be suggested by any of the following:

(a) Any one or a combination of the factors listed for a Type 1 demonstration, paragraph (1), above, as those factors would apply to the existing or proposed discharge under consideration.

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(b) ~~Discharge zone~~ receiving water temperatures (outside the mixing zone) **WHICH, BECAUSE OF THE THERMAL DISCHARGE, ARE** in excess of the upper temperature limits for survival, growth and reproduction, as applicable, of any representative, important species **WHOSE** ~~occurring in the receiving water~~ **NORMAL SEASONAL HABITAT INCLUDES THE PHYSICALLY AFFECTED AREA.**

(c) Receiving water temperature within the mixing zone which fails to conform to minimum requirements for such area.

(d) Receiving water of such quality in the absence of the proposed thermal discharge that the addition or continuance of the discharge may **CAUSE OR AUGMENT POPULATIONS OF AQUATIC ORGANISMS AT LEVELS WHICH** ~~select for excessive nuisance populations of phytoplankton, macroalgae, fouling or boring species, scavenger species or encrusting species.~~ **CREATE NUISANCES. —**

(e) Insufficiency of information needed to select representative, important species; to verify the selection, or to evaluate the effects of the proposed discharge on the selected species. Sufficiency of

information should be determined by ~~the Regional Administrator (or~~
~~Director)~~ **BY THE DIRECTOR,** on the basis of the specific case, /considering the significance of the species in question, the need for the information, its availability or attainability (including time for attaining) and the adequacy of the applicant's other information to allow appraisal of the overall impact of the discharge. If data crucial to the evaluation are not presented, the applicant's Type 2 application should be denied:

Prior consultation with the ~~Regional Administrator (or Director)~~ as to
AND THE DIRECTOR'S WRITTEN RECOGNITION OF THE STUDY PLAN informational needs/should help avoid this result.

(f) Clear indications that the assurance of the protection and propagation of the selected representative, important species will not assure the protection and propagation of the balanced, indigenous community in and on the receiving water body ~~segment.~~ **OR WATER BODY SEGMENT.**

3. Type 3: Biological, Engineering and Other Data.

A failure to demonstrate that the discharge (existing or proposed) is consistent with the assurance of the protection and propagation of the balanced, indigenous community by means of biological, engineering and other data is suggested by any of the following:

(a) Any one or a combination of such factors listed for a Type 1 or Type 2 demonstration as might be applicable. (Paragraphs (1) and (2), above.)

(b) Inadequacy or rebuttal of the applicant's additional data and information to demonstrate the assurance of the protection and propagation of a balanced, indigenous community.

To the extent feasible, the ~~Regional-Administrator~~ ~~(or Director)~~ should define specific Demonstration Type 3 factors at the time the applicant's proposed specific plan of study and demonstration is prepared. (See Chapter 1, subparagraph (e)(1).)

DEFINITIONS

Definitions and descriptions in this section pertain to a number of terms and concepts which are pivotal to the development and evaluation of 316(a) studies. These are developed for the general case to aid the ~~Regional Administrator~~ ~~(or Director)~~ in delineating a set of working definitions and concise end points requisite to a satisfactory demonstration for a given discharge.

(1) Balanced, Indigenous Community.

The regulation provides (40 C.F.R. §122.1(h)):

The term "balanced, indigenous community" is synonymous with the term "balanced, indigenous population" in the Act and means a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and non-domination of pollution tolerant species. Such a community may include historically non-native species introduced in connection with a program of wildlife management and species whose presence or abundance results from substantial, irreversible environmental modifications. Normally, however, such a community will not include species whose presence or abundance is attributable to the introduction of pollutants that will be eliminated by compliance by all sources with section 301(b)(2) of the Act, including alternative effluent limitations imposed pursuant to section 316(a).

A "community" in general is any:

. . . assemblage of populations living in a prescribed area or physical habitat; it is an organized unit to the extent that it has characteristics additional to its individual and population components and functions as a unit through coupled metabolic transformations.

Communities not only have a definite functional unity with characteristic trophic structures and patterns of energy flow but they also have compositional unity in that there is a certain probability that certain species will occur together.^{1/}

All communities typically have characteristics including but not limited to:

- (a) Diversity in its general sense (species richness, equitability and age structure);
- (b) Biological processes, cycles, and periodicities such as regard productivity, reproduction, recruitment, short or long term succession, energy flow and nutrient turnover;
- (c) Spatial characteristics, which may be ordered by the biota as well as the hydrography and geomorphology.

1. Odum, E.P., Fundamentals of Ecology (W. B. Saunders Co., Philadelphia, Pa. (1971)), p. 140.

A "balanced, indigenous" community means a desirable community consisting of fish, shellfish and wildlife plus the biota at other trophic levels which are necessary or desirable as a part of the food chain or otherwise ecologically important to the maintenance of the desirable community. In keeping with the objective of the Act, the community should be consistent with the restoration and maintenance of the biological integrity of the water. (See section 101(a).) However, it may also include species not historically native to the area which:

- Result from major modifications to the water body (such as hydroelectric dams) or to the contiguous land area (such as deforestation attributable to urban or agricultural development) which cannot reasonably be removed or altered.
- Result from management intent, such as deliberate introduction in connection with a wildlife management program.
- Are species or communities whose value is primarily scientific or aesthetic.

Thus, it is not necessary to show that the applicant's discharge is compatible with a community which may have existed in a pristine environment but which has not persisted.

Community imbalance may be evidenced by any one or more of the following:

- Blocking or reversing short or long term successional trends of community development.
- A flourishing of heat tolerant species and an ensuing replacement of other species characteristic of the indigenous community.
- Simplification of the community and the resulting loss of stability.

An imbalanced or nonindigenous community could also be characterized by excessive levels of:

- Species whose dominance results from the introduction of pollutants.
- Species introduced and maintained in residence as a result of habitat destruction by man's activities (for example, dredging).
- Species introduced by human activities (such as aquaculture) which colonize or establish themselves at the expense of endemic communities and which are beyond the limit of management intent. (See section 318, FWPC Act, and 40 C.F.R. Part 115.)

(2) Representative, Important Species.

The regulation provides (§122.1(g)):

The term "representative, important species" means species which are representative, in terms of their biological requirements, of a balanced, indigenous community of shellfish, fish, and wildlife in the body of water into which the discharge is made.

Species should be representative of the community in the sense that a maintenance of water quality conditions assuring the natural completion of their life cycles/will also assure the protection and propagation of the balanced, indigenous community. "Natural completion of THEIR life cycles" refers to species growth, development, reproduction, metabolism and behavior adequate to maintain the species within the community. Species can be important from a direct economic standpoint, as a food chain organism for an economic species, or broadly from the ecological aspect for normal community function and maintenance. For example, to maintain a desired fish species, temperatures must be limited not only to meet the thermal tolerance of the desired species itself but also to maintain species of relevant biotic categories necessary as part of the food web supporting the fish species.

(3) Biotic Categories.

Biotic categories include the following:

- (i) Primary producers--autotrophic organisms that fix CO₂ into organic matter using radiant energy through photosynthesis. Aquatic examples include but are not limited to phytoplankton, periphyton, macrophytes, and macroalgae.
- (ii) Macroinvertebrates--animals that are large enough to be seen by the unaided eye and can be retained by a U.S. Standard No. 30 sieve (28 meshes per inch, 0.595 mm openings). Aquatic examples include but are not limited to mollusks, insects, annelids, and crustaceans.

(iii) Fish--the common usage of this term.

(iv) Economically important species--plant and animal species of present or potential recreational or commercial value as objects of hunt or harvest.

(4) Principal Macrobenthic Species.

Principal macrobenthic species are those dominant macroinvertebrates and plants attached or resting on the bottom or living in bottom sediments. Examples include but are not limited to crustaceans, mollusks, polychaetes, and habitat forming species such as attached macroalgae, rooted macrophytes and coral.

(5) Nuisance Species.

Nuisance species are microbial, plant and animal species, most of which are pollution-tolerant, present in the indigenous community or recruitable from contiguous waters which, by virtue of the direct or indirect effects of the discharge, will be given sufficient advantage to appear in the zone of discharge in large numbers at the expense of other members of the indigenous community. The concept is intended to carry the connotation of "weeds" used in its agricultural sense and may refer to a species with otherwise desirable features. However, any species which indicates a hazard to ecological balance or human health and welfare that is not naturally a feature of the indigenous community must be defined as a nuisance species (e.g., large numbers of fecal streptococci or new blooms of coccoid or blue-green algae).

(6) Migrants.

Migrants are nonplanktonic organisms that are not permanent residents of the area but pass through the discharge zone and water contiguous to it. Examples include the upstream migration of spawning salmon and subsequent downstream run of the juvenile forms, or organisms that inhabit an area only at certain times for feeding or reproduction purposes.

(7) Threatened or Endangered Species.

A threatened or endangered species is any plant or animal that has
SO (1) been/determined by the Secretary of Commerce or the Secretary of the Interior to be a threatened or endangered species pursuant to the Endangered Species Act of 1973, as amended; ; OR (2) BY THE DIRECTOR.

(8) Discharge Zone.

The discharge zone is that portion of the receiving waters which falls within the delta 2°C. isotherm of the plume 30% or more of the time, as defined by data representing a period of at least a few months and preferably indicative of a complete annual cycle.

(9) Water Body Segment.

A water body segment is a portion of a basin the surface waters of which have common hydrologic characteristics (or flow regulation patterns); common natural physical, chemical, and biological processes, and which have common reactions to external stress, e.g., discharge of pollutants. (See 40 C.F.R. §130.2(m).) Where they have been defined, the water body segments determined by the State Continuing Planning Process under section 303(e) of the Act will apply.

(10) Appreciable Harm.

Appreciable harm is damage to the balanced, indigenous community, or to community components which results in such phenomena as the following:

- Substantial increase in abundance or distribution of any nuisance species or heat tolerant community not representative of the highest community development achievable in receiving waters of comparable quality.
- Substantial decrease of formerly indigenous species, other than nuisance species.
- Changes in community structure to resemble a simpler successional stage than is natural for the locality and season in question.
- Unaesthetic appearance, odor or taste of the waters.
- Elimination of an established or potential economic or recreational use of the waters.
- Reduction of the successful completion of life cycles of indigenous species, including those of migratory species.
- Substantial reduction of community heterogeneity or trophic structure.

This definition describes harm which should be considered appreciable. It is not intended that every change in flora and fauna should be considered appreciable harm.

(11) Low Potential Impact.

BY THE DIRECTOR

An existing or proposed discharge may be determined to be a low potential impact discharge, on a case-by-case basis, in either of the following situations:- IF THE DISCHARGE ZONE:

- A. COMPRISES OR WOULD COMPRISE A RELATIVELY SMALL PERCENTAGE OF (1) THE WATERBODY OR WATERBODY SEGMENT, (2) THE SHORE ZONE, (3) THE SHORE TO SHORE DISTANCE, (4) THE CROSS-SECTIONAL VOLUME, OR (5) THE STREAMFLOW;

B. IS NOT OR WOULD NOT BE IN AN AREA OF HIGH BIOLOGICAL VALUE;
AND

C. IF THE THERMAL PLUME DOES NOT OR IS NOT ANTICIPATED TO EFFECT
LIMNOLOGICAL OR BIOLOGICAL PROCESSES OUTSIDE THE DISCHARGE ZONE

- ~~the thermal plume comprises or would comprise a relatively~~
~~small percentage of the shore-to-shore distance and cross-~~
~~sectional area of the fresh water body segment or stream flow~~
~~and is not in an area of high biological value.~~
- The discharge is an off-shore marine discharge which results
or would result in a plume which does not or would not impact
benthic or shoreline organisms, off-shore migratory paths,
spawning areas of fishes or areas of upwelling.

Site-specific considerations which could influence the determination
AND KNOWN BIOLOGICAL PHENOMENA
of low impact include the amount of thermal loading/in the water body
OR IS
segment to which the discharge is/to be made, and lack of any important
spawning areas in the discharge zone.

(12) The definitions of the following terms contained in the regulations
shall be applicable to such terms as used in this guidance manual:
"Effluent limitations," "alternative effluent limitations," "water
quality standards," "section 316(a)," "pollutant," "discharge of a
pollutant," "point source," "discharge" and "pollution."

DEMONSTRATION TYPE I: ABSENCE OF PRIOR
APPRECIABLE HARM (EXISTING SOURCES)(a) Introduction.

An existing source may present information pursuant to this chapter to demonstrate that the thermal component of its discharge has not caused appreciable harm to the balanced, indigenous community.

A Type I demonstration should include the information identified in this paragraph, unless written modifications are developed following consultation with the ~~Regional Administrator~~ ~~(or Director)~~. The demonstration may also include such additional information as the applicant may wish to be considered, provided that the additional information is accompanied by a rationale stating why such information indicates the absence of prior appreciable harm. Information to be submitted includes the following:^{1/}

- Water quality standards information. (Paragraph (b)(1).)
- Records of shutdowns. (Paragraph (b)(2).)
- Water quality related communications. (Paragraph (b)(3).)
- Species information. (Paragraph (b)(4).) ✓
- Discussion of economic and recreational effects. (Paragraph (b)(5).)
- Other known reports on effects of the discharge. (Paragraph (b)(6).)

1. Where field studies are carried out, sample replication should be adequate to determine the precision of the data generated and to conduct appropriate statistical tests.

- Engineering and hydrologic information. (Chapter VII.)
- Thermal load information, if needed. (Chapter IX.)

Information for a full Type I demonstration includes all of the above items. Wherever the applicant can show to the satisfaction of the ~~Regional Administrator (or Director)~~ that its discharge has a low potential impact on the receiving water body segment, the ~~Regional Administrator (or Director)~~ may provide in writing that the Type I demonstration may be ~~limited by omitting~~ ^{MODIFIED SOME OF} the species information described in paragraph (b)(4).

In demonstrating that no appreciable harm has been caused, it is not necessary for the applicant to show that every species which would occur under optimal conditions is present, as long as it demonstrates that the community as a whole, and all major components thereof, are ~~intact~~ ^{AND ANY OTHER PORTION THEREOF AS REQUIRED BY THE DIRECTOR ARE} intact. At the same time, the applicant's demonstration should show the effects of its discharge on species in the entire water body segment: ~~Demonstration of the absence of appreciable harm may not be wholly dependent on exempting a portion of the waters for a mixing zone.~~ ^{OR ANY PORTION THEREOF AS REQUIRED BY THE DIRECTOR.}

The Type I demonstration is not available in either of the following cases:

- The applicant has not been discharging the heated effluent into the body of water for a sufficient period of time (generally at least 1 year) prior to its 316(a) application to allow evaluation of the effects of the discharge.

- The discharge has been made into waters which, during the period of the applicant's prior thermal discharge, were so despoiled as to preclude evaluation of the effects of the thermal discharge on species of shellfish, fish and wildlife.

(b) Applicant's Information.

Information to be submitted includes the following:

(1) Evidence of compliance with applicable water quality standards. The applicant should submit sufficient evidence for the ~~Regional Administrator~~ (or Director) to make a determination of compliance. If any of the evidence reveals non-compliance with water quality standards the applicant should submit a rationale stating why this evidence does not indicate prior appreciable harm to the balanced, indigenous community.

(2) Records of shutdowns and their effects on the aquatic biota. All shutdowns which resulted in the disruption (complete stoppage) of heated effluent flow during the last five years should be documented and some assessment of the known effects of each shutdown should be made by the applicant. If the applicant's records are incomplete or if he has no knowledge of harmful effects for a specific shutdown he should so note and should describe his monitoring efforts in connection with such shutdown. If any effects harmful to aquatic biota have resulted from shutdowns, the applicant should submit a rationale stating why these effects did not constitute appreciable harm to the balanced, indigenous community.

(3) Copies of all water quality related communications (which indicate possible harmful effects) between the applicant and any regulatory agency ~~other than EPA~~ during the last five years. The applicant should submit copies of all such communications or show why he is unable to do so; ~~except that in the case of State administration of the permit program, communications with the State need not be submitted but communications with EPA should be included.~~ For each communication the applicant should also submit a rationale explaining why the concerns reflected in the communication did not reflect appreciable harm to the balanced, indigenous community.

~~(4)(A) -- A list; and an indication of the abundance; of threatened or endangered species and nuisance species; at any trophic level; principal macrobenthic species and species of fish; shellfish and wildlife; in:~~

(4)(A) A LIST OF AQUATIC LIFE AND WILDLIFE, AND AN INDICATION OF THEIR ABUNDANCE, IN THE AREAS AND UNDER THE CONDITIONS DELINEATED THROUGHOUT THIS SUBSECTION (4)(A). THE LIST SHOULD INCLUDE SPECIES: THREATENED OR UNIQUE: INDICATIVE OF WATER QUALITY OR ENVIRONMENTAL CONDITIONS; WITH NUISANCE CAUSING POTENTIAL; IMPORTANT IN ENERGY TRANSFER; OF HISTORICAL SIGNIFICANCE; ECONOMICALLY VALUABLE; OR WHICH MAKE UP APPROXIMATELY 10% OR MORE BY WEIGHT OR NUMBER OF THE PHYTOPLANKTON, ZOOPLANKTON, MACROPHYTES, ATTACHED FILAMENTOUS ALGAE, MACROINVERTEBRATES, ICHTHYOPLANKTON, YOUNG FISH, ADULT FISH OR WILDLIFE.

(i) IN ^tThe discharge zone under existing conditions;

(ii) IN ^tThe water body segment just outside the discharge zone under existing conditions; and

(iii) IN ^tThe water body segment JUST OUTSIDE THE DISCHARGE ZONE under theoretical conditions which would exist ~~by including non-point source influences but excluding stress from point source discharges.~~ WHEN POINT SOURCE DISCHARGERS OF POLLUTANTS ARE IN COMPLIANCE WITH SECTION 301(b) OF THE ACT (P.L. 92-500).

All threatened and endangered species should be LISTED except that no information should be requested that would require field sampling prohibited by the Endangered Species Act, 16 USC 1531 et. seq. The degree to which ~~nuisance species; principal macrobenthic species and species of fish; shellfish and wildlife~~ OTHER SPECIES are to be listed should be determined by consultation between the applicant and the Regional Administrator (or Director).

~~Data-should-be-provided~~ THE LIST SHOULD INDICATE WHICH SPECIES ARE OR WOULD BE PRESENT for each of the following seasonal conditions: summer maximal temperature, fall transitional regime, winter minimal temperature, and spring transitional regime. The Regional-Administrator-(or Director) may request the applicant to conduct more thorough sampling where needed for his analysis of the particular case. BECAUSE THREATENED OR ENDANGERED SPECIES ARE OF SPECIAL CONCERN ADDITIONAL OBSERVATIONS SHOULD BE INCLUDED, SUCH AS BEHAVIOR, MORTALITY, REPRODUCTION, FEEDING, SEXUAL MATURITY, AGE, DISEASE, ETC.

Information relating to the discharge zone should represent conditions throughout the zone (i.e., from the point of discharge to the 2°C. isotherm), unless the Regional-Administrator (or- Director) designates a particular portion of the discharge zone for study.

The estimation (iii) of the species which would be abundant under theoretical conditions should represent the applicant's best approximation based on historical data or the biota of appropriate (relatively unpolluted) nearby water bodies, e.g., at upstream control stations. The basis and limits of comparability of such water bodies should be stated.

THE LIST SHOULD BE PRESENTED IN SUCH A MANNER THAT ANY DIFFERENCES IN SPECIES PRESENT IN THE THREE AREAS CAN BE DISCERNED.

(B) Identification of the reproductive period (dates) and reproductive temperatures for each species of fish and shellfish AQUATIC LIFE listed.

~~{C}--A-map-showing-the-location-within-the-discharge zone-of-reproductive-and-nursery-areas;-migratory-routes;-and-principal macrobenthic-forms-~~

(C) A SCALE MAP OF THE RECEIVING WATERBODY IN THE PLANT VICINITY FEATURING POINTS OF BIOLOGICAL, ECONOMIC, OR SOCIAL IMPORTANCE AT THE LOCAL LEVEL (e.g. SPAWNING AND NURSERY AREAS, SUBSTRATES, BENTHIC FAUNA DISTRIBUTION, DOMINANT CURRENTS, MIGRATORY ROUTES, TRIBUTARY STREAMS, WATER INTAKES, OUTFALLS, ACCESS SITES, ETC.).

(D) Where the Regional-Administrator--(or Director) has reason to believe there may be a specific disease or parasitism problem

as a result of the thermal discharge, information on the incidence of disease and parasitism and on the condition of fish inhabiting the discharge zone and water body segment just outside the discharge zone. This information should include a comparison of affected vs. unaffected populations.

(E) The data called for in subparagraphs (A)-(C) above should be accompanied by a rationale stating why the information provided does not suggest prior appreciable harm to the balanced, indigenous community. This rationale should include a comparison of species and abundance lists and, where appropriate, **EMPHASIS SHOULD BE PLACED ON SPATIAL** estimates of areas impacted and **QUANTITATIVE COMPARED WITH** ~~/levels of impact/for~~ locations of similar habitat within areas (i), (ii) and (iii), subparagraph (A) above, using a statistical method such as coefficient of similarity or analysis of variance. If such statistical methods are inappropriate, an appropriate method of comparison may be substituted and the rationale should include the reasons for the substitution.

(5) A description and discussion of the effect the heated effluent has had on economic and recreational uses of the balanced, indigenous community.

SITE-RELATED

(6) All other known existing?reports concerning the effects of the applicant's discharge on **THE RECEIVING SYSTEM OR ITS BIOTA.** ~~principal macrobenthic species; -threatened or endangered species-or species-of-shellfish, -fish-and-wildlife.~~ If **THE BIOTA,** any of these reports indicate effects harmful to ~~any such species,~~ the applicant should submit a rationale stating why these effects did not constitute appreciable harm to the balanced, indigenous community.

DEMONSTRATION TYPE 2: PROTECTION OF REPRESENTATIVE, IMPORTANT SPECIES

(a) Introduction.

Any existing or new source may present information pursuant to this chapter to demonstrate that the thermal component of its discharge will assure the protection and propagation of representative, important species whose protection and propagation, if assured, will assure the protection and propagation of a balanced, indigenous community.

A Type 2 demonstration should include the information identified in this paragraph, unless the demonstration is changed following consultation with the ~~Regional Administrator~~ (or Director). The demonstration may also include such additional information as the applicant may wish to be considered, provided that the additional information is accompanied by a rationale stating why such information indicates assurance of the protection and propagation of the balanced, indigenous community. Information to be submitted includes the following:^{1/}

- Mixing zone information. (Paragraph (c)(1) or (d)(1); see also Chapter VIII and Appendix A.)
- Water quality standards information. (Paragraph (c)(2) or (d)(2).)
- Record of shutdowns. (Paragraph (c)(3) or (d)(3).)
- Biotic communities information. (Paragraph (c)(4) or (d)(4).)

1. Where field studies are carried out, sample replication should be adequate to determine the precision of the data generated and to conduct appropriate statistical tests.

- Representative, important species information. (Paragraph (c)(5) or (d)(5); see also paragraph (b).)
- Discussion of economic and recreational effects. (Paragraph (c)(6) or (d)(6).)
- Other known reports on effects of the discharge. (Paragraph (c)(7) or (d)(7).)
- Engineering and hydrologic information. (Chapter VII.)
- Thermal load information, if needed. (Chapter IX.)

Information for a full Type 2 demonstration includes all of the above items. Wherever the applicant can show to the satisfaction of the

~~Regional Administrator (or Director)~~ that its discharge has or will have

THE DIRECTOR

a low potential impact on the receiving water body segment, ~~selection of~~
MAY MODIFY THE DEMONSTRATION BY OMITTING SOME OF THE BIOTIC COMMUNITY
~~representative, important species may be limited to fish and shellfish.~~
INFORMATION DESCRIBED IN PARAGRAPHS (C)(4)(a) AND LIMITING THE

REPRESENTATIVE NOTE: The applicant should submit information on all modes of dis-
IMPORTANT SPECIES TO FISH.

charge under consideration. See Chapter I, paragraph (c).

(b) Selection of Representative, Important Species.

(1) General.

(A) ~~The Regional Administrator (or Director)~~ should select representative, important species pursuant to 40 CFR §122.9(b)(2) **SEE APPENDIX I.** (or §122.15(b)(2)). /Such species should consist of one or more species from each of the following biotic categories: macroinvertebrates, fish and economically important species; except that the ~~Regional Administrator (or Director)~~ may determine, based on the characteristics of the receiving water body segment, that species from one or more of these biotic categories need not be included. (See also paragraph (a), above.)

(B) In some cases those species most important in controlling community function are little understood and act in a subtle fashion, so that their role is only evident following environmental degradation. Until such species are identified, it remains prudent in selecting representative, important species in nondegraded environments to consider primarily community dominants. Dominant species include: (i) those with high biomass, and (ii) those of greatest numerical abundance, regardless of biomass. Included among these species would be many species important to energy and nutrient cycling, community structure, and habitat formation.

(C) Where species known to be temperature tolerant or capable of withstanding passage through the proposed discharge are selected as representative, important species (based on their community abundance, potential economic importance or other factors [e.g., American oyster, blue crab, barnacle]), additional more thermally sensitive species in the same biotic category should generally be selected as well, in order better to reflect the thermal sensitivity of an entire biotic category.

(2) Species Selection Where Information is Adequate.

Where information pertinent to species selection is adequate, the ~~Regional Administrator~~ ~~(or Director)~~ should promptly select representative, important species. The applicant may suggest species for his consideration and may, as a part of its demonstration, challenge any selection. Species should be selected as follows:

(A) Applicable State water quality standards.

-- If the State's approved water quality standards designate particular species as requiring protection, these species should be designated, but alone may not be sufficient for purposes of a Type 2 demonstration.

(B) Consultation with Director and with Secretaries of Commerce and Interior.

In the case of species selection by the Regional Administrator, he must seek the advice and recommendation of the Director as to which species should be selected. The Regional Administrator must consider any timely advice and recommendations supplied by the Director and should include such recommendations unless he believes that substantial reasons exist for departure.

The Secretary of Commerce and the Secretary of the Interior, or their designees, and other appropriate persons (e.g., university biologists with relevant expertise) should also be consulted and their timely recommendations should be considered. The Director should also consult with the agency exercising administration of the wildlife resources of the State.

(C) Threatened or endangered species.

Species selection should specifically consider any present threatened or endangered species, at whatever biotic category or trophic level, except that no information should be requested that would require field sampling prohibited by the Endangered Species Act, 16 USC 1531 et. seq.

(D) Thermally sensitive species.

The most thermally sensitive species (and species groups) in the local area should be identified and their importance should be given special consideration, since such species (or species groups) might be most readily eliminated from the community if effluent limitations allowed existing water temperatures to be altered. Consideration of the most sensitive species will best involve a total aquatic community viewpoint.

Thermal sensitivity data includes but is not limited to the data described in paragraph (c)(5)(A), below. Reduced tolerance to elevated temperature may also be predicted, for example, in species which experience natural population reduction during the summer. Species having the greatest northern range and least southward distribution may also possess reduced thermal tolerance.

(E) Economically important species.

Selection of economically important species should be based on a consideration of the benefits of assuring their protection.

(F) Far-field and indirect effects.

Consideration should include the entire water body segment. For example, an upstream cold water source should not be warmed to an extent that would adversely affect downstream biota. The impact of additive or synergistic effects of heat combined with other existing thermal or other pollutants in the receiving waters should also be considered.

(3) Species Selection Where Information is Inadequate.

Where the available information is not adequate to enable the ~~Regional Administrator~~-(or Director) to select appropriate representative, important species, he may request the applicant attempting to make a Type 2 demonstration to conduct such studies and furnish such evidence as may be necessary to enable such selection.* Where species selection is based on information supplied by the applicant, the appropriateness of the species as representative and important is an aspect of the applicant's burden of proof.

The applicant's species selection studies or evidence should normally consist of:

(A) Early submittal of the species information described in paragraph (c)(4) or paragraph (d)(4), below, and the median tolerance limit information described in paragraph (c)(5) or (d)(5), below.

(B) Any available information regarding species identified by community studies, if (i) such community studies have been conducted at existing thermal discharge sites, (ii) the studied community included species also found at the applicant's proposed discharge site, and (iii) such studies have shown that any such species experienced appreciable harm as a result of the thermal component of the discharge. (See Chapter X.)

(C) Other information necessary or appropriate to enable the ~~Regional Administrator~~-(or Director) to address the considerations set forth in paragraph (b)(1), above.

***FOR THE LOWER TROPHIC LEVELS THE DIRECTOR MAY DETERMINE THAT COMMUNITY STUDIES MAY BE SUBSTITUTED FOR REPRESENTATIVE, IMPORTANT SPECIES.**

(c) Applicant's Information--Existing Sources.

Information to be submitted by an existing source includes the following:

ADDRESSING CONFORMITY OF THE DISCHARGE CHARACTERISTICS

(1) Field data ~~that the discharge conforms~~ with an appropriate mixing zone and zone of passage. (See Chapter VIII.) AND MICHIGAN WATER QUALITY STANDARDS).

(2) Evidence of compliance with presently applicable water quality standards. The applicant should submit evidence sufficient to enable the ~~Regional Administrator~~ (or Director) to make a determination OF COMPLIANCE. ~~that water quality standards will be met.~~ If any of the evidence reveals possible noncompliance with water quality standards, the applicant

should submit a rationale stating why the ~~expected~~ deviations from water quality standards ~~will not result in~~ a failure to assure the protection

DO NOT CONSTITUTE
REPRESENTATIVE, IMPORTANT SPECIES AND THE BALANCED, INDIGENOUS
and propagation of the selected/species. (See Chapter VIII.) COMMUNITY.

(3) Records of shutdowns (resulting in complete stoppage of heated effluent flow) and their effects on the aquatic biota. All such shutdowns during the last five years should be documented and some assessment of the known effects of each such shutdown should be made by the applicant. If the applicant's records are incomplete or if he has no knowledge of harmful effects for a specific shutdown, he should so note and should describe his monitoring efforts in connection with such shutdown. If any effects harmful to aquatic biota have resulted from shutdowns, the applicant should submit a rationale stating why these effects did not interfere with the protection and propagation of the SELECTED REPRESENTATIVE, IMPORTANT SPECIES AND THE /balanced, indigenous community. Projections of expected shutdowns and

their projected effects on the aquatic biota should also be made, and the applicant should also submit a rationale stating why the projected effects will not result in a failure to assure the protection and propagation of the balanced, indigenous community. For freshwater fish the nomograph in the Freshwater Thermal Criteria, Appendix B, should be consulted to determine the maximum allowable temperatures of plumes for various ambient temperatures. For non-fish and marine species appropriate information, as available, should be consulted.

~~{4}{A}--A-list-and-data-documenting-the-abundance of-each-selected-representative;-important-species;-threatened-or endangered-species-and-nuisance-species;-at-any-trophic-level; principal-macrobenthic-species;-and-other-important-species-of-fish; shellfish-and-wildlife;-including-all-dominants-(see-paragraph-(b){1}{B}; above)-in:~~

(4)(A) A LIST OF AQUATIC LIFE AND WILDLIFE AND DATA DOCUMENTING THEIR ABUNDANCE IN THE AREAS AND UNDER THE CONDITIONS DELINEATED THROUGHOUT THIS SUBSECTION (4)(A). THE LIST SHOULD INCLUDE SPECIES: THREATENED OR UNIQUE; INDICATIVE OF WATER QUALITY OR ENVIRONMENTAL CONDITIONS; WITH NUISANCE CAUSING POTENTIAL; IMPORTANT IN ENERGY TRANSFER; OF HISTORICAL SIGNIFICANT; ECONOMICALLY VALUABLE; DOMINANT; OR WHICH MAKE UP APPROXIMATELY 10% OR MORE BY WEIGHT OR NUMBER OF THE PHYTOPLANKTON, ZOOPLANKTON, MACROPHYTES, ATTACHED FILAMENTOUS ALGAE, MACROINVERTEBRATES, ICHTHYOPLANKTON, YOUNG FISH, ADULT FISH OR WILDLIFE.

(i) IN the discharge zone under existing conditions,

(ii) IN the water body segment just outside the discharge zone under existing conditions, and

(iii) IN the water body segment just outside the discharge zone under theoretical conditions which would exist when all point source dischargers of pollutants are in compliance with section 301 of the Act (P.L. 92-500).

All representative, important species and threatened or endangered species should be listed, except that no information should be requested that would require field sampling prohibited by the Endangered Species Act, 16 USC 1531, et. seq. The degree to which

OTHER SPECIES

~~nuisance species and other important species of shellfish, fish and wildlife are to be listed should be determined by consultation between the applicant and the Regional Administrator (or Director).~~

SPECIES IN THE LIST AND FOR EACH

Data should be provided for each/of the following

seasonal conditions: summer maximal temperature, fall transitional regime, winter minimal temperature and spring transitional regime. The ~~Regional Administrator (or Director)~~ may request the applicant to conduct more thorough sampling where needed for his analysis of the particular

case. BECAUSE THREATENED OR ENDANGERED SPECIES ARE OF SPECIAL CONCERN ADDITIONAL OBSERVATIONS SHOULD BE INCLUDED, SUCH AS BEHAVIOR, MORTALITY, REPRODUCTION, FEEDING, Information relating to the discharge zone should SEXUAL MATURITY, AGE, DISEASE, represent conditions throughout the zone (i.e., from the point of ETC. discharge to the 2°C. isotherm) unless the ~~Regional Administrator (or~~

~~Director)~~ designates a particular portion of the discharge zone for study.

The estimation (iii) of the species which would be abundant under theoretical conditions should represent the applicant's best approximation based on historical data or on the biota of appropriate (relatively unpolluted) nearby water bodies (e.g., at upstream control stations). The basis and limits of comparability of such water bodies should be stated.

THE LIST SHOULD BE PRESENTED IN SUCH A MANNER THAT ANY DIFFERENCES IN SPECIES PRESENT IN THE THREE AREAS CAN BE DISCERNED.

~~(3) - A scale map showing the location within the proposed discharge zone of reproductive and nursery areas, migratory routes and principal macrobenthic species.~~

(B) A SCALE MAP OF THE RECEIVING WATERBODY IN THE PLANT VICINITY FEATURING POINTS OF BIOLOGICAL, ECONOMIC, OR SOCIAL IMPORTANCE AT THE LOCAL LEVEL (e.g. SPAWNING AND NURSERY AREAS, SUBSTRATES, BENTHIC FAUNA DISTRIBUTION, DOMINANT CURRENTS, MIGRATORY ROUTES, TRIBUTARY STREAMS, DAMS, WATER INTAKES, OUTFALLS, ACCESS SITES, ETC.).

(C) The data called for in subparagraphs (A) and (B) above should be accompanied by a rationale stating why the information provided does not suggest a failure to assure the protection and propagation of a balanced, indigenous community. This rationale should include a comparison of species and abundance lists and, where appropriate, estimates of areas impacted and levels of impact for locations of similar habitat

within areas (i), (ii) and (iii), subparagraph (A) above, using a statistical method such as coefficient of similarity or analysis of variance. IF SUCH STATISTICAL METHODS ARE INAPPROPRIATE, AN APPROPRIATE METHOD OF COMPARISON MAY BE SUBSTITUTED AND THE RATIONALE SHOULD INCLUDE THE REASON FOR THE SUBSTITUTION. TO INCREASES IN TEMPERATURE

(5)(A) The 24-hour median tolerance limit/of species of macroinvertebrates and fish which are dominant in the receiving water

body segment. If such data are not available, the applicant should conduct adequately designed laboratory studies to determine such temperatures. Such studies should be conducted with summer populations or warm acclimated organisms and should employ accepted procedures for median tolerance tests for the particular species. Waters used for the tolerance tests should resemble actual receiving water quality anticipated during the period of the proposed discharge.

This information is for purposes of selecting and verifying the selection of representative, important species. It is useful primarily in predictive situations in the absence of reliable field data. The number of species which should be covered should be determined by consultation between the applicant and the Regional Administrator (or Director). Use of the 24-hour median tolerance limit is preferable for uniformity of comparisons; however, if median tolerance levels for some other time scale are the only data available, they may be used.

(B) The following life history thermal effects data for each representative, important species.

(i) Life History Thermal Effects Data.--For each species, the thermal criteria data identified in this subdivision should be provided,¹/ except that:

- If such data are not available for selected representative, important species of ~~macroinvertebrates,~~ **LOWER TROPHIC LEVELS, SUCH GROUPS** community studies of ~~this group~~ may be conducted at the request of the ~~Regional Administrator~~ (for Director) or at the applicant's option with the advice and consultation of the ~~Regional Administrator~~ (for Director). (See Chapter X.)
- An existing source sited on flowing waters may conduct in situ drift studies to demonstrate that plume temperatures will not be harmful to eggs, larvae and adult of representative, important **OF THE LOWER TROPHIC LEVELS.** macroinvertebrate species/. These studies may substitute for appropriate components of life history thermal effects data.

Thermal effects data to be provided are the following:

- Short-term maximum temperature for survival (upper lethal temperature) of parent during reproduction. (Use acclimation temperature comparable to expected ambient temperature.)

1. This list identifies general categories of data which relate to a wide range of species. In presenting thermal effects data, information categories should be tailored to the individual species being considered.

- Short-term maximum temperature for survival (upper lethal temperature) of appropriate life stage during the summer.
- Optimum temperature for growth of appropriate life stage (juveniles or adults).
- Minimum avoidance temperature (motile species).
- Maximum temperature at which normal incubation and larval development occurs.
- Normal reproductive dates (site specific) and temperatures (general) at which reproduction occurs.

The applicant's life history thermal effects data may be based on criteria and information published pursuant to section 304(a) of the Act; information set forth in Appendix A; adequately designed laboratory or field studies, or published studies on latitudinally comparable populations, as provided in subparagraph (E) below. Thermal effects data may be presented in tabular or narrative form, but in either case detailed explanations of assumptions made should accompany all data presented. AND PAGE NUMBER.
All information should be footnoted as to source.

(ii) An evaluation of the effects of the proposed discharge on the representative, important species. The evaluation should be presented in tabular form/ **SIMILAR TO THAT** as indicated on Sample Table A, below. One table should be submitted for each representative, important species. The evaluation should indicate the distribution and duration

SAMPLE TABLE A

EVALUATION OF THERMAL DATA

SPECIES: _____		(Common Name)		(Scientific Name)	
Biological Activity to be Protected	Temperature	Data Source and Page	Area of Discharge Zone Exceeding Max. Temperature (Acres Covered and What Conditions, Including Time Period)	Activity Excluded From Discharge Zone by Heat % of Area Activity Excluded	Effects Outside Discharge Zone
Max. for Survival of Parent					
Max. for Summer Survival					
Optimum Growth					
Minimum Avoidance					
Max. for Development					
Normal Reproduction Dates & Temperatures					

1. This table identifies activities which relate to a wide range of species. In presenting thermal evaluations, activity categories should be tailored to the individual species being considered. The table headings constitute summaries of the thermal effects data list set forth at subparagraph 5(b)(1), above.

2. Use acclimation temperature comparable to expected ambient temperature.

of potential exposure of the species (i) in the discharge zone and (ii) in the water body segment just outside the discharge zone during worst case and average conditions during each season.

(iii) A rationale stating why the information submitted pursuant to this subparagraph suggests that the heated discharge will not result in a failure to assure the protection and propagation of the selected species. Where data necessary to complete the life history thermal effects data are unavailable and community studies have not been substituted, the rationale should so note and indicate why obtaining the data is not feasible or not necessary to the analysis of the effects of the discharge or proposed discharge.

(C) When the ~~Regional Administrator~~-(or Director) believes it is appropriate, information on the chill requirements for gamete formation of selected species.

(D)(i) Except as provided in subparagraph (ii), below, the applicant's life history thermal effects data should consist of any applicable data contained in water quality criteria published by the Administrator pursuant to section 304(a) of the Act, when such data are published as final (rather than proposed) criteria. Life history thermal effects data compiled by EPA are provided in Appendix B and should be used where 304(a) criteria are not available or inapplicable.

(ii) Where 304(a) data or data provided by the Regional Administrator are not applicable or the applicant wishes to contest any of such data, the applicant may submit thermal tolerance data based on well-documented field deduction, adequately designed laboratory studies or published studies on latitudinally comparable populations. For information based on laboratory studies, a detailed description of methodology should be given or referenced. For information based on published studies, the complete bibliographic reference, including page number, should be given and the use of such other sources should be explained and justified. For information based on latitudinally comparable populations, the basis and limits of comparability should be stated.

(6) An assessment of the effect the heated effluent has had and an indication of the expected effects it will have on economic or recreational uses of the selected species.

SITE-RELATED

(7) All other known existing/reports concerning the effects of the proposed discharge on the ~~the/aquatic biota~~. If any of these reports indicate a probability of effects harmful to ~~aquatic~~ **THE** biota, the applicant should submit a rationale stating why the proposed discharge will nonetheless assure the protection and propagation of the balanced, indigenous community.

(d) Applicant's Information--New Sources.

Information to be submitted by a new source includes the following:

(1) Data showing that the proposed discharge will conform with an appropriate mixing zone and zone of passage. (See Chapter VIII.)
AND MICHIGAN WATER QUALITY STANDARDS.

(2) Evidence of compliance with presently applicable water quality standards. The applicant should submit evidence sufficient to enable the ~~Regional Administrator~~ (or Director) to make a determination that water quality standards will be met. If any of the evidence reveals possible noncompliance with water quality standards, the applicant should submit a rationale stating why the expected deviations from water quality standards would not result in a failure to assure the protection **REPRESENTATIVE, IMPORTANT AND A BALANCED, INDIGENOUS COMMUNITY.** and propagation of the selected/species: / (See Chapter VIII.)

(3) Projections of expected shutdowns resulting in complete stoppage of heated effluent flow, and their projected effects on the aquatic biota. The applicant should submit a rationale stating why the projected effects will not result in a failure to assure the protection and propagation of a balanced, indigenous community. For freshwater fish the nomograph in the Freshwater Thermal Criteria, Appendix B, should be consulted to determine the maximum allowable temperatures of plumes for various ambient temperatures. For non-fish and marine species appropriate information, as available, should be consulted.

(4)(A) A list and an indication of the abundance of species as called for in subparagraph (c)(4)(A), above. These data should be supplied for:

(i) The proposed discharge zone under existing conditions.

(ii) The water body segment just outside the proposed discharge zone under existing conditions.

(iii) The proposed discharge zone under projected conditions during discharge.

(iv) The water body segment just outside the proposed discharge zone under projected conditions during discharge.

(v) The water body segment just outside the proposed discharge zone under theoretical conditions which would exist when all point source discharges of pollutants are in compliance with section 301(b) of the Act.

(B) A map as called for in subparagraph (c)(4)(B), above.

(C) A rationale as called for in subparagraph (c)(4)(C), above. The rationale should state why the proposed discharge will **REPRESENTATIVE, IMPORTANT SPECIES AND** assure the protection and propagation of/a balanced, indigenous community. Where appropriate, the rationale should include estimates of areas which may be impacted and levels of impact which may be expected to occur.

~~(B) - The information called for in subparagraph (c)(4)(B), above, except that such information may be limited to the area of the proposed discharge zone.~~

(5) Life history thermal effects data, evaluations and rationale as called for in subparagraphs (c)(5)(A) and (c)(5)(B) and, if appropriate, (c)(5)(C), above.

(6) An assessment of the effect the heated effluent is expected to have on economic or recreational uses of the selected species.

SITE-RELATED

(7) All other known existing/reports concerning possible effects of the proposed discharge on ~~the aquatic biota~~. If any of these reports indicate a probability of effects harmful to ~~aquatic biota~~, the applicant should submit a rationale stating why the proposed discharge will nonetheless assure the protection and propagation of the balanced, indigenous community.

DEMONSTRATION TYPE 3: BIOLOGICAL, ENGINEERING AND OTHER DATA.

(a) Introduction.

Any existing or new source may present biological, engineering and other data to demonstrate that a proposed effluent limitation is more stringent than necessary to assure the protection and propagation of a balanced, indigenous community. The purpose of the Type 3 demonstration is to provide for the submittal of any information which the Regional Administrator ~~-(or Director)~~ believes may be necessary or appropriate to facilitate evaluation of a particular discharge. It also provides for submittal of any additional information which the applicant may wish to be considered. Each Type 3 demonstration should consist of information and data appropriate to the case.

(b) Definition of Type 3 Demonstration; Written Concurrences.

Detailed definition of a generally applicable Type 3 demonstration is not possible, because of the range of potentially relevant information; the developing sophistication of information collection and evaluation techniques and knowledge, and the case-specific nature of the demonstration. Prior to undertaking any Type 3 demonstration, the applicant should consult with and obtain the advice of the Regional Administrator ~~-(or Director)~~ regarding a proposed specific plan of study and demonstration. (See Chapter I, subparagraph (c).) Decision guidance may also be suggested. (See Chapter III, paragraph 3.)

In general, Types 1 and 2 represent baselines for the depth of analyses. While Type 3 information may be different in thrust and focus, proofs should be at least as comprehensive as in those types and should result in similar levels of assurance of biotic protection.

(c) Rationales.

Each item of information or data submitted as a part of a Type 3 demonstration should be accompanied by a rationale stating why it represents evidence that the proposed discharge will assure the protection and propagation of a balanced, indigenous community. The rationale should include an explanation as to why this demonstration approach was selected.

NOTE: THE APPLICANT SHOULD SUBMIT INFORMATION ON ALL MODES OF DISCHARGE UNDER CONSIDERATION. SEE CHAPTER 1, PARAGRAPH (c).

ENGINEERING AND HYDROLOGIC DATA

(a) Introduction.

This chapter describes the engineering and hydrologic information which should normally be included in any 316(a) demonstration. It also suggests formats for presentation of such information. The ~~Regional Administrator~~ (or Director) may request additional information or excuse the applicant from preparation of portions of this information as the situation warrants. The engineering and hydrologic information to be submitted should consist of all information reasonably necessary for the analysis. Where information listed in this chapter is not relevant to the particular case, it should be excused.

The engineering and hydrologic information and data supplied in support of a 316(a) demonstration should be accompanied by adequate descriptive material concerning its source. Data from scientific literature, field work, laboratory experiments, analytical modeling, infrared surveys and hydraulic modeling will all be acceptable, assuming adequate scientific justification for their use is presented. **CITATIONS SHOULD BE TO PAGE NUMBER.**

(b) Plant Operating Data.

(1) Cooling water flow. Complete Table B (indicate units).

(2) *Submit a time-temperature profile graph indicating temperature on the ordinate and time on the abscissa. The graph should indicate status of water temperature from natural ambient through the

***IF WINTER OPERATION OR PLUME BEHAVIOR IS DIFFERENT THAN SUMMER, PROVIDE APPROPRIATE PARALLEL INFORMATION.**

TABLE B

COOLING WATER CHARACTERISTICS^{1/}

% Unit Load	Unit Loading % Time	Intake Velocity*	Rate of Cooling Water Flow	Condenser ΔT	Discharge ΔT^{**}	Rate of Total Water Discharge
40						
50						
60						
70						
80						
90						
100						

^{1/} If seasonal variations occur, this should be so indicated.

*Intake velocity data should be provided at the point where the cooling water first enters the intake structure. Variations in intake velocity with changes in ambient conditions (e.g., river flow, tidal height, water level) should be noted.

**Discharge ΔT = Discharge Temperature-Intake Temperature. (In many cases, condenser ΔT is equivalent to discharge ΔT . However, for plants with supplemental cooling facilities, this is not the case.)

cooling system and discharge until its return to ambient. Worst case, anticipated average conditions, and ideal (e.g., minimum time/ temperature impact) conditions should be illustrated, preferably on the same graph.

(3) Submit a graph or table indicating the total heat rejected via the discharge as a function of time, including short-term (daily) and long-term (annual) fluctuations.

(4) For plants using fresh water, complete Table C, indicating units.

TABLE C
Water Use Table

	Fresh Water Consumption	Receiving Water Evaporation*
Maximum Design		
Monthly**		
Average Annual		

*Increase in evaporation caused by the thermal discharge.

**If variable, please indicate degree of variations by percent or extremes. This may be illustrated graphically.

(c) Hydrologic Information.

(1) Flow: Provide the information called for in paragraph (i), (ii), (iii) or (iv), as applicable to the site:

(i) Rivers: flow -- monthly means and minima (7 day, 10 year low flows).

(ii) -- Estuaries: -- freshwater input, -- tidal flow volumes, net tidal flux -- monthly means and minima for each.

(iii) Reservoirs: flow through time, release schedules --
-- monthly means and minima.

~~(iv) -- Oceans: -- tidal heights and information on flushing
characteristics.~~

(2) Currents: Provide the information called for in paragraph
(i), (ii) or (iii), as applicable to the site:

(i) Rivers: maximum, minimum, and mean current speed,
giving seasonal (or monthly) fluctuations.

~~(ii) -- Estuaries: -- tidal and seasonal changes in current
speed and direction.~~

(iii) Large lakes and oceans: offshore prevailing currents;
local tidal and seasonal changes in current speed
and direction.

(3) Tabulate or illustrate monthly means and summer extremes
in stratification characteristics ~~and salinity variations~~ in the vicinity
of the intake and discharge. If intake and discharge conditions are
identical, so state and provide only one tabulation or illustration.

(4) Tabulate or illustrate ambient temperature of the receiving
waters, giving monthly means and extremes for the preceding 10 years as
data availability permits. If comparable site waters are used, indicate
the basis and limits of comparability.

(5) Indicate intake and receiving waters depth contours at
0.5 m. intervals. Provide other significant hydrological features
(e.g., thermal bar characteristics).

(d) Meteorological Data.

If energy-budget computations are included as part of the 316(a) demonstration, provide the following meteorological data for the plant site, giving both monthly means and seasonal extremes. Indicate units.

- (1) Wet bulb air temperature.
- (2) Dry bulb air temperature.
- (3) Wind speed and direction.
- (4) Long wave (atmospheric) radiation.
- (5) Short wave (solar) radiation.
- (6) Cloud cover.
- (7) Evapotranspiration.

(e) Outfall Configuration and Operation.

Provide the following information on outfall configuration and operation, indicating units expressed.

- (1) Length of discharge pipe or canal _____
- (2) Area and dimensions of discharge port(s) _____
- (3) Number of discharge port(s) _____
- (4) Spacing (on centers) of discharge ports _____
- (5) Depth (mean and extreme) _____
- (6) Angle of discharge as a function of:
 - A. horizontal axis _____
 - B. vertical axis _____
 - C. current direction(s) _____

(7) Velocity of discharge:

-- A. maximum _____

B. most usual _____

(f) Thermal Plume Characteristics. AND IDENTIFICATION OF THE DISCHARGE
ZONE

Provide the following information on thermal plume characteristics:
WITH ERROR ESTIMATES

(1) Scale drawings/accurately depicting the plume's configuration under various hydrological conditions. Drawings should provide isotherms in at least 2°C. increments and should indicate 3 spatial dimensions to the extent possible. Such drawings should be supplied for ~~low and slack tides or low and average flows during~~ each of the four

seasons*, AND IN RIVERS, FOR LOW AND AVERAGE FLOWS. THE RATIONALE FOR DESIGNATION OF THE DISCHARGE ZONE (CHAPTER III (8)) SHOULD BE INCLUDED.

(2) Indicate by similar illustration the expected variation in plume isotherms under variable conditions of climate. A qualitative discussion of the effect of changes in relevant meteorological parameters may be provided if adequate information is available.

(3) Graph plume velocity* vs. distance.

(i) along centerline

(ii) along bottom

(g) Chemical and Water Quality Data.

Section 316(a) specifies that the thermal component of the discharge must be evaluated "... taking into account the interaction of such thermal component with other pollutants. . . ." While data on such synergistic effects are limited, certain information will assist the Regional Administrator (or Director) in assessing potentially harmful interactions. The following information should be provided:

*ONE FOOT PER SECOND UNITS TO A MINIMUM OF ONE FOOT PER SECOND.

- (1) The amount of chlorine used daily, monthly and annually, the frequency and duration of chlorination, and the maximum total chlorine residual at the point of discharge obtained during any chlorination cycle.
- (2) A list of any other chemicals, additives, or other discharges which are contained in the cooling water discharge including (TRADE) the name, amount (including frequency and duration of application and the maximum concentration obtained prior to dilution), chemical composition and the reason for addition.
- (3) The effect of the thermal discharge on the dissolved oxygen levels in the plume and in the receiving waters in increments of 0.5 mg/l.

VIII

MIXING ZONE GUIDELINES^{1/}

(a) Introduction

(1) General

The protection and propagation of a balanced, indigenous
community in the receiving water body/segment must be assured. Consistent with achieving this assurance, in many cases one or more areas of
A WATERBODY, SEGMENT OF, OR REGION OF
/ a segment may be designated as mixing zones. Within such zones, reduced water quality may be allowed, provided that the zones, individually and in combination with other point and nonpoint source influences on the
WATERBODY OR
/ segment, are so limited as not to preclude the statutory protection and propagation requirement.

The mixing zone to be employed should be the zone set forth in applicable water quality standards. Where the language of the standards is not sufficiently precise to identify the mixing zone with certainty, the ~~Regional Administrator~~ (or Director) should promptly identify the mixing zone called for by the standards. In the case of any new source, the ~~Regional Administrator~~ (or Director) should specifically identify an
AND/OR MIXING ZONE
appropriate zone of passage/at the outset of the demonstration.

If the applicant is seeking alternative effluent limitations which would be based on a mixing zone other than the mixing zone provided by the applicable water quality standards, the submittal should describe

1. See also Appendix A.

the location, size and shape of the desired zone and the water quality within the zone. This information should be accompanied by a rationale stating why the existence of such a zone will be consistent with the assurance of the protection and propagation of the balanced, indigenous community. The rationale should consider the mixing zone materials accompanying this guidance and should include an evaluation of the relationship of the recommended mixing zone with other discharges (present and potential, thermal and non-thermal) to the receiving water body segment. The rationale may also include such other information as the applicant may wish to present.

Any mixing zone must be limited to a temporal and spatial (area, volume, configuration and location) distribution which will assure the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife in and on the receiving water body. If the applicant's submittal involves review of the mixing zone, the ~~Regional Administrator~~ ~~for~~ Director should:

- Consider the principles set forth in this chapter and Appendix A, as appropriate.^{1/}
- Consider applicable water quality standards.^{2/}

1. Guidelines for mixing zones in fresh water are set forth in paragraph (b) of this chapter; guidelines for marine mixing zones are included at paragraph (c). Appendix A contains additional materials which may be considered in connection with fresh water mixing zones. The guidelines may be supplemented with information on mixing zones contained in the report of the National Academy of Sciences, "Water Quality Criteria" (1973).

2. The statutory rule of section 316(a) that effluent limitations should "assure the protection and propagation of a balanced, indigenous population" requires maintenance of receiving water body characteristics which will assure that protection and propagation, notwithstanding any possible departure from otherwise applicable water quality standards, including their mixing zone provisions.

- ~~In the case of a determination by the Regional Administrator,~~ consult with the Director.
- In the case of interstate or international waters, consult with the responsible water quality management agencies of such other jurisdictions.
- Consider of any pertinent information submitted by the applicant or however obtained.

(2) Definition.

A mixing zone is an area contiguous to a discharge where receiving water quality does not meet the requirements otherwise applicable to the receiving water. Description and delineation of mixing zones pose difficult regulatory problems. It is obvious that any time an effluent is added having lesser quality than the receiving water, there will be a zone of mixing. The definition as used here is that receiving water area where exceptions to otherwise applicable water quality standards are granted. It is important to recognize that by this definition the effluent or plume may be identifiable at distances or in places outside the defined mixing zone. This definition should not be confused with engineering usages, often employed in designing outfalls, and that refer to the area before complete mixing occurs. The mixing zone is a place to mix and not a place to treat effluents.

(3) General Principles.

There are several principles that are applicable to most mixing zones and provide the basis upon which to establish conditions for them. A most important principle is that since by their definition mixing zones provide for exceptions to otherwise applicable water quality standards and damage may occur, the permissible size of the mixing zone is dependent on the acceptable amount of damage. For obvious regulatory reasons, as well as biological ones, the size and shape of the mixing zone should be specified so that both the discharger and the regulatory agency know its bounds. A mixing zone should be determined taking into consideration unique physical and biological features of the receiving water, but there are principles about the size and shape that can aid in decision making.

(4) Physical Size.

For physical reasons, the size of the mixing zone may need to be larger for very large discharges than for very small ones. The permissible size depends in part on the size of the receiving water; the larger the body of water, the larger the mixing zone may be without exceeding a given portion of the total receiving water. The acceptable size for a mixing zone depends also on the number of mixing zones on a body of water. The greater the number, the smaller each must be in order to keep the area devoted to mixing zones sufficiently small. In this connection, future growth of industry and population must be considered.

(5) Quality Within Zones.

There are upper limits to the permissible degree of degradation within mixing zones. All mixing zones should be free of:

- (i) Materials that will settle to form objectionable deposits.
- (ii) Floating debris, oil, scum, and other matter.
- (iii) Substances producing objectionable color, odor, taste, or turbidity.
- (iv) Substances and conditions or combinations thereof in concentrations which produce nuisance aquatic life.

The conditions that may exist in the mixing zone should be determined for each site but general principles can guide. There should be no conditions permitted that are rapidly lethal to locally important and desirable aquatic life. Therefore, rapid mixing is desirable. Many planktonic organisms are such weak swimmers that they must drift through the mixing zone and will be exposed to its conditions for the period of time required to drift through and in lakes or reservoirs this may be an extended period. Therefore, toxicity or adverse conditions should be such that these organisms can survive without undue damage or stress while they are passing through. There are concentrations of some pollutants that attract animals but are also lethal or clearly adverse. Such pollutants that attract aquatic life are more troublesome than those pollutants that are avoided. For example, crowding together in a heated plume enhances disease susceptibility and transmission. Concentrations

OF TOXICANTS

/ exceeding the 96-hour LC_{50} should not be permitted. ANY PLACE IN THE MIXING ZONE INHABITABLE BY FISH.

NOT APPLICABLE
(6) / Fresh Water/Marine Water Distinction.

For purposes of this chapter, water may be delineated as fresh water or marine water on the basis of salinity or tide. Marine waters include all oceanic waters and those under the influence of the ocean. Specifically, they include waters of the coastal region and those extending into bays, estuaries, river mouths, and other lowlands to that point at which either (a) the salinity falls below 0.5 parts per thousand, or (b) a predictable tide no longer persists. All waters above this point should be considered fresh water. At boundary locations, the Regional Administrator (or Director) may indicate, based on the hydrological and biological features of the site, whether the mixing zone, if any, should be evaluated on the basis of fresh water or marine water principles.

(b) Fresh Water Mixing Zones.

(1) Summary.

The following discussion is a tool to aid decision-making when mixing zones are established. It cannot replace knowledge of local areas or common sense, but it can assist in identifying key elements upon which to base decisions.

The basic components are:

- (i) Delineation of the most valuable areas and consideration of biological values.
- (ii) Selection of a level of protection for each area and determination of the portion of the area to be allocated to all mixing zones.
- (iii) Limitation of the permissible conditions of quality in the mixing zones.
- (iv) Allocation to present and future dischargers.

NOTE: This paragraph discusses general principles regarding fresh water mixing zones. A proposed optional system for establishing fresh water mixing zones based on receiving waters' biological value is set forth at Appendix A.

(2) Biological Considerations.

From a biological standpoint, the location of the mixing zone is important. It is generally true that an offshore discharge has a lesser potential for adverse effect than a comparable onshore discharge into shallow water. Shallow water in lakes, reservoirs, and rivers is generally more biologically valuable and productive. There are several reasons and some of them are critical during site selection.

Food production is greater in the shallow water zone because light penetration is sufficiently deep to support growth of periphyton, attached algae, and rooted vegetation; nutrients from runoff are commonly more plentiful; terrestrial food organisms are more plentiful; there is a greater variety of substrates (sand, sediment, and rubble as contrasted to mostly fine sediment in deeper water) that provide habitat for many kinds of food organisms; and oxygen concentrations are more favorable because wave action and diffusion processes transport oxygen to the bottom.

The density and variety of fish are greater in shallow water because most fish spawn in shallow areas and their progeny utilize these areas as nursery grounds; prior to spawning migrations into tributary streams, numerous fish species concentrate in shallow waters until conditions are optimal for spawning runs; cover provides more protection

from larger predators; the more diverse substrates support a greater variety of species in larger numbers than in the more uniform habitat of deep waters; and, in rivers and streams, many fish species migrate through the shallow shore zones. Shallow, protected bays and coves on large lakes and reservoirs are often the most biologically important, probably for the above reasons, but also because wind and wave action are reduced and the bottom is more stable.

Mixing zones in shallow water affect a greater benthic area as the result of limited dilution volume and natural turbulence resulting in top to bottom mixing. In some instances, however, the very shallow water (less than a few meters) can be less productive due to an unstable substrate of shifting sand and sediment caused by wave action by wind or shipping activities.

The location of mixing zones should consider migratory routes of important species, and they should not be positioned so as to form a block to such movements. If less than one-half the width of a stream or river is used, then discharges on opposite sides will not constitute a block. In this connection, future dischargers must also be considered. Thus it is good practice to limit single mixing zones to one-third or

one-quarter of the width of a stream or river. IF WATER QUALITY CONDITIONS IN THE MIXING ZONE ITSELF ASSURE PASSAGE OF ORGANISMS WITHOUT ACUTE OR LATENT EFFECTS THE APPLICANT MAY DEMONSTRATE THAT A GREATER MIXING ZONE IS APPROPRIATE.

Recreational uses, such as water contact sports and sport fishing, are concentrated in the shore zone also. This zone is important to the aesthetic appeal of water bodies, as well.

(3) Positioning.

The positioning of mixing zones relative to each other is important. Special concern is needed where mixing zones contain different components (such as heat and copper) and may be adjacent or overlap. Overlapping or superimposed mixing zones are acceptable if BIOLOGICAL EFFECTS MEET OTHER GUIDELINE RESTRAINTS. ~~there is not an additive effect and the toxicity limits given below are met.~~ WITH OVERLAPPING MIXING ZONES In this way, less area is used for a given number of dischargers but regulatory problems may be made more difficult.

(4) Shape.

The shape of mixing zones is important because the boundaries must be easily located for compliance purposes. Actual plumes are not fixed in either size or shape and therefore cannot be used as boundaries. The prudent approach is to adopt a simple configuration that is easy to locate in the body of water and yet avoids excessive impingement on important areas. AN AREA EQUIVALENT TO THAT OF A CIRCLE WITH A SPECIFIED RADIUS LIMITS THE AREAL EXTENT, BUT FAILS TO LIMIT THE LOCATION IN LAKES. ~~A circle with a specified radius is preferable.~~ Other shapes could be used, depending upon unusual site requirements. "Shore-hugging" plumes should be avoided.

An accepted fact is that the plume will not conform exactly to arbitrary configurations but within some portion of that configuration mixing to quality as good as receiving water standards must occur. It is true that water currents may cause the plume to bend different directions on different days, but the intent is to require that the plume quality be as good as receiving water standards by the time the boundary is

reached. It is obvious then that the practice of calling the plume a mixing zone is prohibited. Indeed, some sites may require diffusers or other devices to meet the requirements. For future discharges, these limitations may force site selection considerations and if so--everyone will gain.

NOT APPLICABLE

(c) /Marine Water Mixing Zones.

(1) Introduction.

General recommendations are presented to aid in defining mixing zones for heated water discharge into estuarine and coastal waters. New sites should be selected to permit effective employment of a near bottom diffuser discharge. This is recommended to optimize the dissipation of heat by vertical diffusion through the water column and minimize the surface area impacted by excessive temperature. Considerations of location, configuration and maximum size are outlined for single mixing zones. In summary, specific recommendations for marine mixing zones include:

(A) Location at sites with good flushing characteristics and a bottom community of minimal ecological importance.

(B) Siting which will not result in thermal addition to the intertidal zone.

(C) Discharge at depth sufficient to permit good sub-surface dilution of the heated effluent without excessive impact to the bottom nor excessive loss of cross-sectional water column area for pelagic and planktonic life.

(D) Maximum width of the mixing zone at slack water not exceeding ten-percent of the shore-to-shore distance of a waterway nor of the cross-sectional area of a waterway.

Final delineation of a mixing zone must take into consideration other mixing zones as well as pertinent socio-economic factors, which are highly site specific. These guidelines must be supplemented by careful consideration of such factors. Two cases in point are (a) local water quality conditions and (b) mixing zones, thermal or non-thermal and existing or potential. Factors such as these can greatly influence permissible size and location of a new thermal mixing zone. However, guidelines to weight these factors have not yet been developed for the marine environment.

(2) Location Guidelines.

(A) Mixing zones should not impinge over five percent of the time on shallow shoreline waters subject to appreciable natural summer atmospheric heating which normally experience wide tidal or diurnal fluctuations in temperature. Maintenance of normal temperature fluctuations, both in amplitude and frequency, is imperative for protection of the indigenous shallow water and intertidal community. Shallow water is defined for this purpose as the extreme low water line minus three feet for sites having a maximum shoreline current in excess of 0.5 knots; or as extreme low water minus six feet at sites having less shoreline current.

(B) Sites having good flushing characteristics are preferable. - -

(C) Sites having a dense, well-developed bottom community are not desirable.

(D) Open coastal waters are more preferable for mixing zones than the estuary due to the latter's dominant role as a plankton dependent nursery ground.

(E) Sites bordered by a narrow intertidal zone are preferable; sites bordered by wide intertidal flats or marshes are undesirable due to the potential adverse influence of a heated discharge on these shallow, highly productive habitats.

(3) Size and Configuration Guidelines.

(A) The slack water maximum dimension of any mixing zone should not exceed ten percent of the respective shore-to-shore dimension of a waterway, nor occupy over ten percent of its cross-sectional area. A 90 percent zone of passage should be maintained for the passive flow of planktonic algae, zooplankton and developmental stages of invertebrates and fishes and for the active passage of highly motile forms such as fishes and crustacea.

(B) The cross-sectional area devoted to a mixing zone should be minimized. Biologically, loss of surface area can be as important as volume consideration in the marine environment. At well-selected new sites, near-bottom diffuser discharge should be at a depth which would not only meet receiving water criteria at the surface

but which also results in a mixing zone without excessive horizontal dimensions.--

(4) Multiple Mixing Zone Considerations.

The maximum number of mixing zones that are ecologically permissible, existing or potential, in a single estuary or adjacent open coastal strand is dependent on variations in hydrography, geography and local thermal and biotic characteristics. Thus, the question can only be resolved on a case-by-case basis, and analysis of the total thermal load on the segment may be appropriate. (See Chapter IX.) The characteristics enumerated in paragraph (2) regarding preferable mixing zone location also pertain to the question of multiple mixing zones. Where site conditions are highly favorable, multiple mixing zones may be considered. A potentially preferable site could be a coastal strand which does not receive estuarine waters. Long-shore migration of fishes, the nature of the bottom community and other factors would have to be taken into consideration as well. In contrast, within small estuaries, multiple power plant siting may be precluded entirely by the increased adverse impact on planktonic life caused by cooling water pumping of an additional plant or by other thermal or non-thermal mixing zones, existing or proposed.

THERMAL LOAD ANALYSES

Introduction

For 316(a) evaluations, the major emphasis is on developing information to support a determination as to the assurance of the protection and propagation of the balanced indigenous community (Chapters IV-VII) and the determination of an allowable mixing zone based on biological considerations (Chapter VIII). While the "mixing zone" approach may constitute the primary means of evaluating thermal discharges in specific cases, at times an additional calculation of the total thermal load on the receiving water body segment is needed. Such a calculation should be made whenever there is indication that the effect of one or more thermal discharges discharging during critical hydrological (low flow), meteorological or biological conditions may cause critical temperature conditions in the segment.

Basically the approach in thermal load analyses is to measure total heat contribution from all discharges entering a water body, determining the volume and/or surface area of the receiving water under consideration, and compare the possible physical changes in the receiving water with pertinent water quality standards and criteria (temperature, temperature change, BTU's, etc.) or other temperature requirements determined as a part of the 316(a) process. The need for total thermal load calculation should be especially considered in the case of new sources to be located near existing facilities or the reservation of thermal load allocations to future discharges to certain receiving waters.

The following outline addresses several points to consider:

I. When is the load analysis required?

A. When there are occurring or suspected violations to water quality standards and/or criteria relating to temperature (including standards which are in existence and any changes to them which have been proposed by the State or which the Regional Administrator has requested the State to adopt) during critical conditions (low flow, adverse meteorology, intense local biological activity [e.g., spawning season], peak output of plant, etc.); or

B. When there are several thermal discharges in close proximity or where future growth plans indicate the installation of several new facilities (power plants, steel mills, etc.); or

C. Where thermally loaded waters are specifically identified under Section 303(d)(1)(B) and (D) of P.L. 92-500.

II. When is the load analysis sufficient?

A. When the analysis has identified the probable compliance with or violations of water quality standards and criteria relating to temperature (whether such standards are in existence, proposed by the State or requested of the State by the Regional Administrator) for daily variations of plant operation or receiving water conditions, various seasons, extremes of low flow and weather, etc.; and

B. When the analysis provides sufficient detail regarding the control strategy(ies) which are needed (i.e., the rate of heat rejection limits [e.g., in BTU/hr.] allocated to each discharger under consideration); and

C. If models are used for the analysis, when the accuracy of these models is firmly established. Therefore, specific accuracy levels for the model being used in a particular case should be reported by the applicant (temperature, heat load, etc.).

III. Information to be obtained by the applicant.

A. See Chapter VII "Engineering & Hydrologic Information."

B. If the applicant is the only significant thermal discharger on the receiving stream where violations are suspected, he will bear the burden of supplying data for the entire study (both near and far field).

C. If there are several dischargers within the study area, each discharger is responsible for data collection in his immediate area.

1. All dischargers in the study area should collect data useful for the specific model being used.

2. The ~~Regional Administrator or State~~ Director may be responsible for requesting data collection by dischargers other than the applicant, for organizing all data and for conducting the overall load allocation study. Exceptions include:

a. If one facility is discharging nearly all the heat, it should carry the burden of the study.

b. Joint studies by major heat dischargers should be conducted.

IV. Information to be supplied by the Regional Administrator or
~~State Permit-Program~~ Director.

A. Applicable water quality standards and/or criteria relating to temperature, including standards which are in existence and any changes to them which have been proposed by the State or which the Regional Administrator has requested the State to adopt.

B. Where there are multiple dischargers, it may be necessary for the Regional Administrator (or Director) to conduct the overall load analysis (far field).

V. Procedures.

Thermal load analyses require the use of acceptable analytical methods and techniques. Several methods are illustrated in the technical literature and range from those using very simplified techniques of low level accuracy to others which incorporate complex computer programs. Therefore, prior to commencing its analysis the applicant should submit information on the methodology to be employed; provide justification for its selection and use, and obtain the written concurrence of the Regional Administrator ~~(or Director)~~ in the proposed methodology.

Community Studies(a) Introduction

This chapter identifies community studies which may be appropriate in any 316(a) demonstration. In particular, the applicant may submit results of such studies as a substitute for certain information items of a Type 2 demonstration (see Chapter IV, paragraphs (c)(5)(B) and (d)(5), above) or as a supplement to any demonstration; or ~~the Regional Administrator (or Director)~~ ^{TO SATISFY THE DIRECTOR'S} ^{FOR} may request such studies as a supplemental information item.

For purposes of Section 316(a), community studies for the groups, primary producers, zooplankton, and macroinvertebrates, are appropriate. These studies focus on parameters which are indicative of an array of species within a biotic category. They seek, therefore to relate the effects of a discharge or proposed discharge to the community of organisms of a given biotic category, rather than to individual species in that category.

Studies described herein are neither exhaustive nor all-inclusive. The ~~Regional Administrator (or Director)~~ may expand or delete listed informational items as site-specific conditions may warrant. For greater detail the following references may be consulted:

- (1) Biological field and laboratory methods for measuring the quality of surface waters and effluents, C. I. Weber (ed.). National Environmental Research Center, Office of Research and Development, U. S. EPA, Cincinnati, Ohio (1973).

(2) American Nuclear Society Standards 18.4: Guidelines for
(THIS DOCUMENT IS
aquatic ecological surveys for nuclear power plants/near
completion).

(b) Data Collection

(1) General. The informational items described below are some of the possible community studies which can be undertaken. Collection of data during all four seasons is preferable; however, the Regional Administrator (or Director) may determine that less information is adequate for a particular study. The taxonomic level to which organisms are identified depends on needs, experience, and available resources. This level should be determined and kept constant in each major group for the whole study. For existing plants samples should be collected within the discharge zone, just outside the discharge zone, and at a comparison site upstream of the plant, if appropriate, or in a nearby similar waterway unaffected by thermal discharge. Where baseline data exist, comparison may instead be based on conditions at the discharge site (within and just outside the discharge zone) before and after the beginning of plant operation: **BUT IN ANY CASE REFERENCE STATIONS SHOULD BE INCLUDED.** Comparisons should be based on samples taken from similar habitats and bases and limits of comparability/should be stated. **AND BASES**
For new plants samples should be collected from the proposed discharge zone. Comparisons will necessarily be predictive in nature. These will be discussed in greater detail below (see paragraph (c)(2)). Where field studies are carried out, sample replication should be adequate to

determine the precision of the data generated and to conduct appropriate statistical tests.

For some of the parameters enumerated below, when taken alone, it is difficult to interpret whether a community is imbalanced and under stress, or not. Yet, when taken as an aggregate, they may prove useful in evaluating the degree of similarity between a community receiving a thermal discharge and the community at a comparable site which is not receiving heat.

(2) Primary producers

(A) Phytoplankton

- (i) quantitative measure of taxonomic composition
- (ii) species diversity (including equitability)
- (iii) total cell counts
- (iv) standing crop biomass (mg/l)
- (v) chlorophyll content
- (vi) productivity

(B) Periphyton

- (i) quantitative measure of taxonomic composition
- (ii) standing crop biomass
- (iii) chlorophyll content
- (iv) productivity

(C) Macrophyton and macroalgae

- (i) quantitative measure of taxonomic composition
- (ii) standing crop biomass
- (iii) chlorophyll content
- (iv) productivity

(3) Zooplankton

- (A) quantitative measure of taxonomic composition
- (B) species diversity (including equitability), SEE REFERENCE CITED, (a)(1))
- (C) standing crop biomass

(4) Macroinvertebrates

- (A) quantitative measure of taxonomic composition
- (B) species diversity (including equitability)
- (C) standing crop biomass
- (D) benthic community respiration

NOT APPLICABLE

- (5) / Fouling or boring communities. For marine waters studies of fouling or boring communities may be conducted by maintaining panels at several stations distributed throughout the discharge zone, just outside the discharge zone and at a comparison site or through before and after comparisons at the discharge site (see paragraph (b)(1), above). Sets of panels should be suspended horizontally to collect benthic components as well as being placed vertically. The resulting fouling or boring communities may indicate consequences of thermal addition for the indigenous community. Such consequences may include

competitive exclusion due to the flourishing of heat-tolerant and nuisance species, failure of larval settlement of certain species, and economic loss due to fouling or boring.

(c) Data Evaluation.

The data called for in paragraph (b) above, should in each case, be accompanied by a rationale stating how the information presented suggests the assurance of the protection and propagation of a balanced indigenous community.

- (1) For existing sources the rationale should include a comparison of affected vs. unaffected communities using standard statistical analysis. It should be noted that a statistically significant difference in any community parameter does not necessarily indicate detriment and also that lack of such a difference does not insure protection; scientific judgment should prevail since no hard and fast decision rule is available given the present state of the art. Where a potentially adverse statistically significant difference between an affected and unaffected area is found (e.g., a large decrease in either the total number of species present or the diversity index, the applicant should present an estimation of the physical area covered by this difference and an explanation why this difference does not suggest a failure to assure the protection and propagation of a balanced, indigenous community.

(2) For new sources, comparisons will necessarily be predictive.

In such cases the data called for in paragraph (b) should serve as a baseline to the predictive comparisons described below. Because these methods are predictive and therefore less precise analytical tools, any assumptions which are made should be clearly defined. Predictive comparisons include:

(A) Predictive modeling of biological response to a thermal discharge, using a specific ecological model developed for that purpose. Verification should be carried out using data from a comparable existing source, making the assumptions necessary to do so. Bases and limits of comparability and their effects upon modeling results should be explained.

(B) Extrapolation of future community effects using community data from a well studied existing thermal discharge which is comparable to the proposed discharge. Features of comparability include similar geomorphology, substrate type, environmental regime, hydrography, water quality, latitude and discharge size and design, or existence of a highly similar biological community. It is recognized that a comparable site may not exist in a majority of cases.

For predictive modeling, the rationale should include a discussion of the validity of the model; including the verification procedure; and a showing of long-term (e.g., one or more years) system stability. For extrapolation from other communities, the rationale should include a discussion of the comparability of the studied site and the proposed discharge site; and should also include an explanation why the existing discharge is consistent with the protection and propagation of a balanced, indigenous community.

APPENDIX A

Biological Value System for Establishing Mixing Zones

This appendix sets forth a proposed system for establishing fresh water mixing zones based on allocation of the biological value of the receiving waters. ~~Use of the system is optimal.~~

(a) Delineation of Biotic Zones.

The total area allocated to mixing zones can be more easily and accurately allocated than can areas for individual ones. This is so because the error, if any, is distributed proportionately to each mixing zone and the decision considers the potential combined effects of all discharges. This must be done by competent staff but only needs to be decided once.

The mixing zone discussion in Chapter VIII identifies certain biotic zones (e.g., shore zone) that are more important than others and are related to water depth. Depth then can be used as a convenient tool to delineate the various zones.

The light intensity at which oxygen production in photosynthesis and oxygen consumption by respiration of the plants concerned are equal, is known as the compensation point, and the depth at which the compensation point occurs is called the compensation depth. This depth will vary, of course, in any segment and is dependent upon season, time of day, cloudiness of the sky, condition of the water (turbidity), and other factors. An approximate determination of the compensation depth as the means of differentiating the shallow and deep water zones is simpler than conducting a thorough biological characterization. If such a characterization, based on the various biological populations, is available in adequate detail, it should be used but if not, the following can be substituted.

In general, the compensation depth is that depth at which light intensity is about 1 per cent of full sunlight intensity. This depth should be determined using photometric techniques and measurements should be obtained with a frequency capable of establishing the average condition. As an alternative, Secchi disk readings represent the zone of light penetration down to about 5 per cent of the solar radiation reaching the surface and a depth 3 - 4 times the Secchi disk depth is a good approximation of the compensation depth. Either technique should suffice and there are usually more data available on Secchi disk readings than photometric measurements.

The use of light penetration to distinguish the shallow and deep water zones should be an acceptable means of delineating the more productive and biologically shallow water zone and the deeper, less critical (and, therefore, less sensitive) zones. Stratified water in which, during summer months, trout and salmon are restricted, to a limited temperature, to the deeper, hypolimnetic waters, cannot be differentiated as readily since the deeper, cooler water is critical to the continued presence of these valued species. Once the compensation depth has been determined, a depth contour is used to calculate the surface area of each zone.

(b) Biological Value.

Since some biotic zones are more important than others, mixing zones should be located in the less important ones or in those that are larger in area. A relative biological value for the various zones is needed in order to allocate portions of each zone for mixing.

To be sure, this biological valuation cannot be strictly objective but must utilize professional, expert opinion of biologists familiar with the local situation. Highly valued trout waters in two-story lakes or areas inhabited by endangered species can be given an infinite value and no mixing zones allowed in those areas. Biological value can be based on the species diversity of the zones and the value made proportional to the ratio of species diversity in various zones. Current-swept mid-channels of large rivers or deep waters, devoid of D.O. in large lakes, both can be given low value. Where data are inadequate, it may be possible to use only two values--a value of two for one zone known to be more important than the second zone. A value of ten for a "highly" important zone could be given instead of a value of two as in the preceding situation.

Occasions will arise when there is not a competent data base upon which to establish biological value. In such cases, one may assume the biological value to be the same for both areas. (i.e., the value of a unit area is inversely proportional to the total area in each zone).

Assignment of total biological value is important because it defines upper limits on the amount of each biotic zone that may be used for mixing. This assignment offers dischargers a chance to select better sites for installation and allows the ~~Regional Administrator~~ (or Director) to encourage dischargers to locate in the areas least likely to be damaged.

The biological value "weighs" the various zones, thus allowing the same percent of the value of each (but not area) to be used for mixing without stressing one zone more than another.

(c) Level of Protection (Degree of Risk).

What percent of total biological value, then, should be used? Conditions necessary for all life history processes may not be provided in mixing zones. When an excessively large percent of a segment is made up of mixing zones, the population of some species will decline and an unpredictable chain of events may ensue. Furthermore, estimates of an acceptable percent of an aquatic environment that can be allocated to mixing zones must be conservative, since predictive capabilities are uncertain.

Determination of the amount of a segment's biological value to be allocated to mixing zones is based on a variety of criteria, including type of water body, water velocity, depth, the number and type of habitats, migration patterns, and the nature of the local food chain. Level of productivity, water temperature, ability of tributary waters to provide recruitment, human value (aesthetic, commercial and sport fishing, recreational), endangered species, and other criteria must all be considered.

It is acknowledged that any estimate of the amount of area assigned to mixing zones, that will not have an unacceptable effect on a water segment, must be based on expert opinion. However, it is apparent that there are varying degrees of protection desired or required for different water bodies or in different words, the acceptable risk differs with location. Consequently, degrees of protection are recommended: Maximum level of protection for unique or fragile environments; low level of protection for the less valuable environment or an environment most capable of withstanding insults; and a moderate level of protection intermediate between the two. The per cent of biological value to be consigned to mixing zones could be one per cent for maximum protection and ten percent for a low level of protection with specific values from one to ten being selected for intermediate protection.

(d) Allocation Alternatives.

(1) The final step is not a biological one, but an administrative process of allocation to present and to future dischargers. This decision cannot be universal. However, there are several considerations that should be given attention when making this decision. Available projections on future municipal-industrial growth can be evaluated to estimate the potential future need for mixing zones. The planned plant closures due to obsolescence, etc. should be known. Also, some classes of industry are utilizing production or waste treatment technology based on more efficient use of surface waters (e.g., closed-cycle cooling, water reclamation and re-use).

Basically, the determination of specific mixing zone sizes is a process of allocation of which there are several options:

(A) All mixing zones the same size.

Advantages--simple, direct and easy to calculate.

Disadvantages--large volume discharges would require a much greater level of treatment than would small volume discharges. Allows small volume dischargers to discharge relatively large quantities of persistent pollutants.

(B) Each discharger in a general class of discharges (paper mills, metal finishing, municipal waste, power plant) is given the same size mixing zone, but different classes are given different sizes.

Advantages--simple and direct, could better allow for general differences in volume of discharge, could take into account general persistence or toxicity of different classes of discharges.

Disadvantages--there is a rather large variation in discharge volumes in any given class. Penalizes large plants and favors small ones.

(C) Mixing zone directly proportional to the volume of the discharge (e.g., for each unit volume the mixing zone would be a unit area).

Advantages--calculation simplified, superficially fair to all dischargers.

Disadvantages--encourages dilution pumping to obtain a larger zone.

(D) Mixing zone proportional to some monotonic increasing function of the discharge volume, that has a finite upper bound.

Advantages--in contrast to "(C)" would discourage dilution pumping and would not unduly favor large volume discharges.

(E) Mixing zone apportionment based on toxic units that consider toxicity and volume of waste.

This approach has as a basis the actual cause for concern--hazard to aquatic life. Its chief disadvantage lies in the probable frequent need for toxicity tests before decisions can be made.

(2) Example.

To illustrate how these suggestions might be employed to establish mixing zone sizes and placement, consider the following general example.

Assume that on the basis of the foregoing considerations a water segment has been divided into m zone types, with known areas (A_1, A_2, \dots, A_m) and correspondingly assigned relative biological values (BV_1, BV_2, \dots, BV_m). Also, assume that there are presently n dischargers on the segment with relative flow rates of (Q_1, Q_2, \dots, Q_n). From this information, we must establish a policy for mixing zones for the present and any future dischargers on this segment.

Several decisions of critical importance must be made before we may proceed. The level of protection $1\% \leq p \leq 10\%$ and the fraction of biological value $0 < \theta \leq 1$ allotted to present dischargers must be chosen. Also, an allocation scheme to divide the deemed expendable biological value among dischargers must be decided.

Given these factors, we proceed as follows:

(A) The total biological value of the segment is calculated by taking the sum of the biological value for each zone so that

$$BV = BV_1 + BV_2 + \dots + BV_m$$

(B) The total amount of biological value deemed expendable for present and future mixing zones is calculated to be

$$pBV$$

(C) The amount of biological value allocated to present dischargers is thus

$$\theta pBV$$

(D) The fraction of this to be allocated to an individual discharger is to be made proportional to some as yet unspecified function $f(Q)$ of a discharger's flow rate. Thus, if we define

$$S_n = f(Q_1) + f(Q_2) + \dots + f(Q_n)$$

the amount of biological value to be given to a discharger with flow rate Q_k is

$$U_k = \frac{\Theta_p BV}{S_n} f(Q_k)$$

(E) The only task remaining in order to explicitly define U_k is to give $f(Q)$ a specific form.

The choice of $f(Q)$ is dependent upon the goals desired in a segment and thus is not unique, but should as a minimum be monotonically increasing and have a finite upper bound. One such function that meets these criteria is

$$f(Q_k) = \frac{Q_k}{Q_k + \bar{Q}(W-1)}$$

where $\bar{Q} = (Q_1 + Q_2 + \dots + Q_n)/n$ is the average flow rate and $1 \leq W \leq \infty$ is the ratio of the biological value that would be allocated to a theoretical discharger with an infinite flow rate to that allocated to a discharger with flow rate \bar{Q} . The larger W is, the more biological value is allotted to large dischargers. If $W=1$, then all dischargers would receive the same number of biological units independent of their flow rates. If $W=\infty$, then each discharger would receive an amount that is in the same proportion as the flow rate. (See figure 2)

A compromise between these two extremes would be to linearly interpolate to find a half-way point. Since one value is infinite, the interpolation would have to be done on a reciprocal scale, thus interpolating half way between the reciprocals we have, that

$$1/1 = 1, \quad 1/\infty = 0 \quad \text{halfway is} \quad 1/2 = 1/W \quad \text{or} \quad W = 2.$$

Using $W=2$, our function $f(Q_k)$ has the simple form

$$f(Q_k) = \frac{Q_k}{Q_k + \bar{Q}}$$

and the allocation formula in this instance may be expressed as

$$U_k = \frac{\Theta_p BV Q_k}{S_n (Q_k + \bar{Q})}$$

(F) Once U_k is specified, it is up to the individual discharger to choose his own mixing zone as he sees fit, subject only to the constraints that it is circular in form and contains no more than his allocated number of biological units. In order to protect the very shallow shore areas and give the discharger incentive to discharge into deeper water, any land in the discharger's chosen circle can be given the same biological value as the water zone in his circle with greatest biological value.

If the mixing zone circle is contained totally in one type of zone, then the radius r_{jk} of a circle in the j^{th} zone allocated to a discharger of flow rate Q_k is

$$r_{jk} = \sqrt{\frac{U_k A_j}{\pi BV_j}}$$

If a mixing zone is in more than one zone type, the radius of the circle must be obtained by trial and error, where a radius is specified and the number of biological units in the circle is computed to be:

$$\frac{A_{1k} BV_1}{A_1} + \frac{A_{2k} BV_2}{A_2} + \dots + \frac{A_{mk} BV_m}{A_m}$$

where A_{jk} is the area of the circle in the j^{th} zone given to the k^{th} discharger. The radius is then adjusted until the computed biological units are equal to the allotted number of biological units.

Present dischargers are free to obtain a mixing zone according to this formula and future dischargers can be issued permits on the same basis, until the total number of allocated biological units are exhausted.

In addition, it should be noted that by using this procedure, it is possible to utilize a proportion pBV/BV_j of the area of the j^{th} zone type for mixing zones. Thus, an upper bound for each type zone might also be established that would limit the total area that could be taken for any one type of zone by not issuing any permits in that type of zone, once this upper limit was met.

As a guide to following these concepts, consider the following concrete numerical example.

A segment, shown in Figure 1, is divided into two zones on the basis of a compensation point which occurs at a 10-meter depth. The areas ($A_1, A_2, m = 2$) and corresponding relative biological values (BV_1, BV_2) of each zone are specified and the total biological value computed as indicated in Figure 1. We shall also assume that we have three ($n=3$) dischargers on the segment with relative flow rates shown in Table 1. Choosing ($p = .02, \theta = .5, W = 2$) we obtain the allocation formula

$$U_k = \frac{.02182 Q_k}{Q_k + 3}$$

and the allocation of biological units also indicated in Table 1.

If an individual with relative flow rate of 9 was to have his circle entirely in the first zone, his radius would be

$$r = \sqrt{\frac{(.02182)(9)(35)}{(9+3)(\pi)(2)}} = .3019$$

or an individual with relative flow rate of .5 units, all in zone 2, would have a radius of size

$$r = \sqrt{\frac{(.02182)(.5)(25)}{(.5+3)(1)}} = .2792$$

Conclusion

In essence, the approach in these guidelines focuses on the need to consider the collective effects of all discharges to the segment or large portion of the segment. The guidelines identify critical overall considerations and suggest decisional alternatives. They discuss allocation of the total acceptable mixing zone area among present and future discharges.

The Regional-Administrator-(or Director) can employ the decision-making process of these guidelines and still use available local expertise and common sense. Thus, the determinations will be visibly rational and consistent among discharges; at the same time each decision will be tailored to the local situation.

Table 1.

$p = .02, \theta = .5, W = 2$

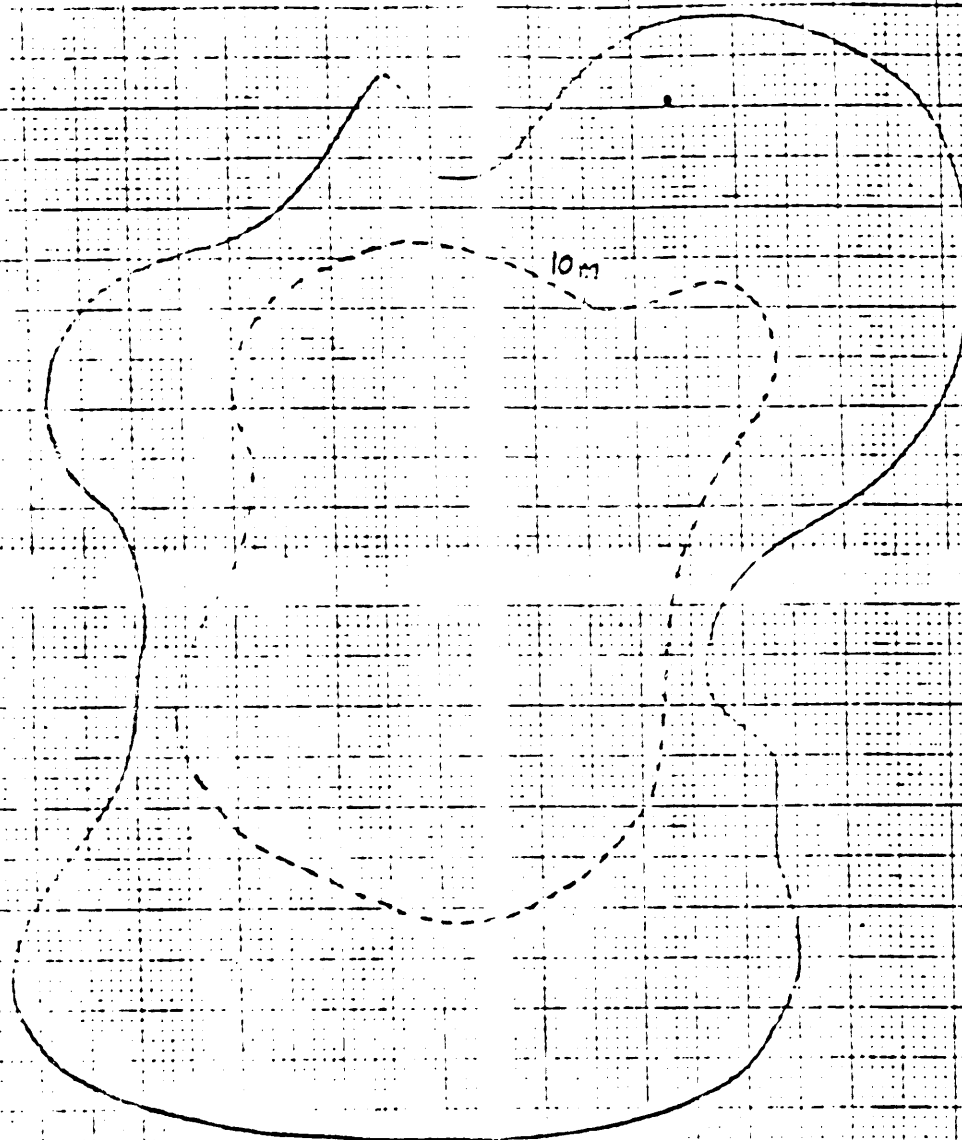
Numerical Example

k	Q_k	$f(Q_k) = \frac{Q_k}{Q_k+3}$	$U_k = \frac{(.5 \times .02 \times 3)f(Q_k)}{1.375} = .02182f(Q_k)$
1	1	.25	.00545
2	3	.50	.01091
3	5	.625	.01364
\bar{n}	9	1.375	.03

$$\bar{Q} = (1 + 3 + 5)/3 = 3$$

$$S_n = .25 + .5 + .625 = 1.375$$

FIGURE 1: BASIC DATA FOR
HYPOTHETICAL BIOLOGICAL
AND NUMERICAL EXAMPLE



ZONE 1 $\leq 10m$ $A_1 = 35$ $BV_1 = 2$

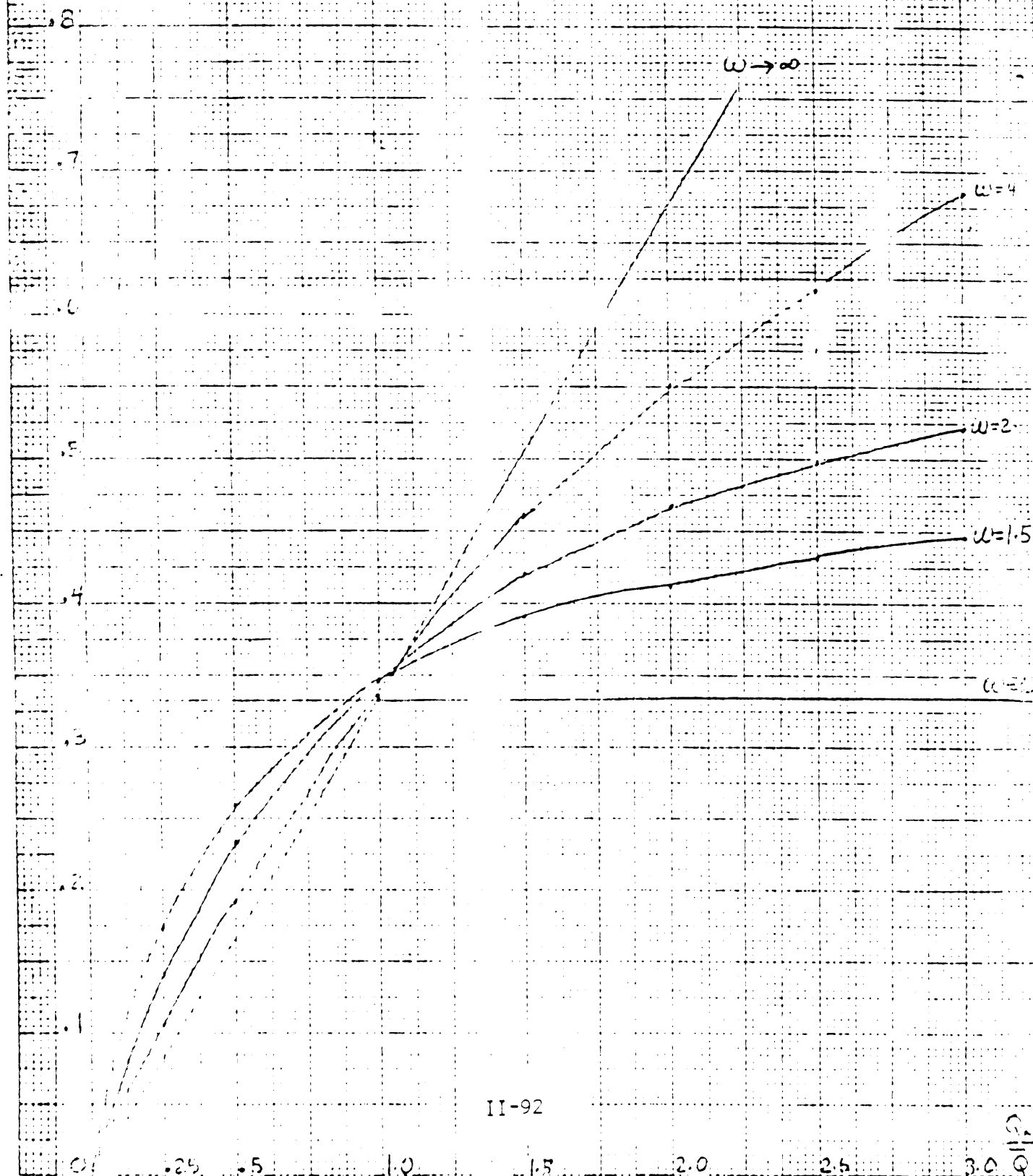
ZONE 2 $> 10m$ $A_2 = 25$ $BV_2 = 1$

$$A = A_1 + A_2 = 60$$

$$BV = BV_1 + BV_2 = 3$$

PROPORTION OF
PRESENT EXPENDABLE
BIOLOGICAL RESOURCES
GIVEN TO THE READER
WITH A FLOW RATE OF Q_0
BASED ON EXAMPLE
SHOWN IN TABLE 1

FIGURE 2
EFFECT OF ω ON
ALLOCATION



APPENDIX B

1

FRESH WATER TEMPERATURE CRITERIA

Acceptable temperature limits in fresh water during any time of the year are:

a. A maximum weekly average temperature that:

1. In receiving waters during the warmer months (approximately April through October in the North and March through November in the South) is one-third of the range between the optimum temperature for growth and the ultimate upper incipient lethal temperature for the most sensitive important species (or appropriate life stage) that is normally found at the location at that time (see Table 1).

2. In the heated plume during the cooler months (approximately mid-October to mid-April in the North and December to February in the South) corresponds to the appropriate ambient temperature in the nomograph in Figure 1. This should protect against most fish mortality when the temperature to which the fish are exposed in the plume rapidly drops to the ambient temperature. In some areas this limit may also be applicable in the summer.

3. During reproduction seasons (generally April-June and September-October in the North and March-May and October-November in the South) meets specific site requirements for successful maturation, migration, spawning, egg incubation, fry rearing, and other reproductive functions of important species as presented in part in Table 2.

or 4. At a specific site is found necessary to preserve normal species diversity or prevent undesirable growth of nuisance organisms.

and b. maximum temperatures for short-term exposures at any season as developed using the resistance time equation:

$$\log (\text{Time in min.}) = a + b (\text{Temp. in } ^\circ\text{C})$$

where a and b respectively are intercept and slope, which are characteristics of each acclimation temperature for each species (see later detailed discussion). During the spawning season this limitation, which was designed to prevent juvenile and adult fish mortality, would not be adequately protective of reproduction. Consequently, this limitation will be superseded by short-term maximum temperatures based on maximum successful spawning and egg incubation temperatures.

Local requirements for reproduction should supersede all other requirements when they are applicable. Detailed ecological analysis of both natural and man-modified aquatic environments is necessary to ascertain when these requirements should apply.

Available data on temperature requirements for growth and reproduction, lethal limits for various acclimation temperature levels, and various temperature-related characteristics of many of the more important freshwater fish species are included in Appendix A.

Rationale (Temperature):

Living organisms do not respond to the quantity of heat but instead, to degrees of temperature or to temperature changes caused by transfer of heat. Organisms have upper and lower thermal tolerance limits, optimum temperatures for growth, preferred temperatures in thermal gradients, and temperature limitations for migration, spawning and egg incubation. Temperature also affects the physical environment of the aquatic medium (e.g., viscosity, degree of ice cover, and oxygen capacity); therefore, the composition of aquatic communities depends largely on temperature characteristics of the environment.

Because temperature changes may affect the composition of an aquatic community, an induced change in the thermal characteristics of an ecosystem

may be detrimental. On the other hand, altered thermal characteristics may be beneficial, as evidenced in some of the newer fish hatchery practices and at other aquacultural facilities. The general difficulty in developing suitable criteria for temperature (which would limit the addition of heat) is to determine the deviation from "natural" temperature a particular body of water can experience without adversely affecting its desired biota. Whatever requirements are suggested, natural diurnal and seasonal cycles must be retained, annual spring and fall changes in temperature must be gradual, and large unnatural day-to-day fluctuations should be avoided. In view of the many variables, it seems obvious that no single temperature rise limitation can be applied uniformly to continental or large regional areas; the requirements must be closely related to each body of water and to its particular community of organisms, especially the important species found in it. These should include invertebrates, plankton, or other plant and animal life that may be of importance to food chains or otherwise interact with species of direct interest to man. Since thermal requirements of various species differ, the social choice of the species to be protected allows for different "levels of protection" among water bodies. Although such decisions clearly transcend the scientific judgments needed in establishing thermal criteria for protecting selected species, biologists can aid in making these decisions. Some measures useful in assigning levels of "importance" to species are: (1) high yield or desirability to commercial or sport fisheries, (2) large biomass in the existing ecosystem (if desirable), (3) important links in food chains of other species judged important for other reasons, and (4) "endangered" or unique status. If it is desirable to attempt strict preservation of an existing ecosystem, then the most sensitive species or life stage may dictate the criteria selected.

Criteria for making recommendations for water temperature to protect desirable aquatic life cannot be simply a maximum allowed change from natural temperatures. This is principally because a change of even one degree from an ambient temperature has varying significance for an organism, depending upon where the ambient level lies within the tolerance range. In addition, historic temperature records or, alternatively, the existing ambient temperature prior to any thermal alterations by man are not always reliable indicators of desirable conditions for aquatic populations. Multiple developments of water resources also change water temperatures both upward (e.g., upstream power plants or shallow reservoirs) and downward (e.g., deepwater releases for large reservoirs) so that ambient and natural temperatures at a given point can best be defined only on a statistical basis. Criteria for temperature should consider both the multiple thermal requirements of aquatic species and requirements for balanced communities. The number of distinct requirements and the necessary values for each require periodic reexamination as knowledge of thermal effects on aquatic species and communities increases. Currently definable requirements include:

- Maximum sustained temperatures that are consistent with maintaining desirable levels of productivity (growth minus mortality);
- Maximum levels of thermal acclimation that will permit return to ambient winter temperatures should artificial sources of heat cease;
- Temperature limitations for survival of brief exposures to temperature extremes, both upper and lower;
- Restricted temperature ranges for various stages of reproduction, including (for fish) gonad growth and gamete maturation, spawning migration, release of gametes, development of the embryo and larva, commencement of

independent feeding (and other activities) by juveniles; and temperatures required for metamorphosis, emergence, and other activities of lower forms;

- Thermal limits for diverse compositions of species of aquatic communities, particularly where reduction in diversity creates nuisance growths of certain organisms, or where important food sources or chains are altered;

- Thermal requirements of downstream aquatic life where upstream warming of cold water sources will adversely affect downstream temperature requirements.

Thermal criteria must also be formulated with knowledge of how man alters temperatures, the hydrodynamics of the changes, and how the biota can reasonably be expected to interact with the thermal regimes produced. It is not sufficient, for example, to define only the thermal criteria for sustained production of a species in open waters, because large numbers of organisms may also be exposed to thermal changes by being pumped through the condensers and mixing zone of a power plant. Design engineers need particularly to know the biological limitations to their design options in such instances. Considerations such as impingement of fish upon intake screens, mechanical or chemical damage to zooplankton in condensers, or effects of altered current patterns on bottom fauna in a discharge area may reveal non-thermal impacts of cooling processes that may outweigh temperature effects. The environmental situations of aquatic organisms (e.g., where they are, when they are there, in what numbers) must also be understood. Thermal criteria for migratory species should be applied to a certain area only when the species is actually there. Although thermal effects of power stations are currently of greater interest, other less dramatic causes of temperature change including deforestation, stream channelization, and impoundment of flowing water must be recognized.

Available data for temperature requirements for growth and reproduction, lethal limits for various acclimation temperature levels, and various temperature-related characteristics of many of the more desirable freshwater fish species are included in the Appendix. General temperature criteria for these species are summarized in Tables 1 and 2.

Terminology Defined

Some basic thermal response of aquatic organisms will be referred to repeatedly and are defined and reviewed briefly here. Effects of heat on organisms and aquatic communities have been reviewed periodically (e.g., 1, 2, 3, 4, 5, 6). Some effects have been analyzed in the context of thermal modification by power plants (7, 8, 9, 10, 11). Bibliographic information is available in various publications (12, 13, 14, 15, 16, 17).

The thermal tolerance range is adjusted upward by acclimation to warmer water and downward by cooler water, although there is a limit to such accommodation. The lower end of the range usually is at zero degrees centigrade (32° F) for species in temperate latitudes (somewhat less for saline waters), while the upper end terminates in an "ultimate incipient lethal temperature" (18). This ultimate threshold temperature represents the "breaking point" between the highest temperatures to which an animal can be acclimated and the lowest of the temperatures that will kill the warm-acclimated organism.

At the temperatures above and below the upper and lower incipient lethal temperatures, survival depends not only on the absolute temperature but also on the duration of exposure, with mortality occurring more rapidly the further the temperature departs from the threshold.

Because the equations based on research on thermal tolerance predict 50 percent mortality, a safety factor is needed to assure no mortality. Several studies have indicated that a two degree centigrade (3.6° F) reduction of an upper lethal temperature results in no mortalities within an equivalent exposure duration (19, 20). The validity of a two degree safety factor was strengthened by the results of Coultant (21), which showed that for median mortality at a given high temperature, for about 15 to 20 percent of the exposure time there was induced selective predation on thermally shocked salmon and trout. This also amounted to reduction of the effective stress temperature by about two degrees centigrade. Unpublished data from subsequent predation experiments showed that this reduction of about two degrees centigrade also applied to the incipient lethal temperature. The level at which there is no increased vulnerability to predation is the best estimate of no-stress exposure that is currently available.

Maximum Weekly Average Temperature for Growth

Occupancy of habitats by most aquatic organisms often is limited within the thermal tolerance range to temperatures somewhat below the ultimate upper incipient lethal temperature. This is the result of poor physiological performance at near lethal temperatures (e.g., growth, metabolic scope for activities, appetite, food conversion efficiency), interspecies competition, disease, predation, and other subtle ecological factors. This complex limitation is evidenced by restricted southern and altitudinal distributions of many species. On the other hand, optimum temperatures (such as those producing fastest growth rates) are not generally necessary at all times to maintain thriving populations and are often exceeded in nature during summer

months. Moderate temperature fluctuations can generally be tolerated as long as a summer maximum upper limit is not exceeded for long periods.

A true temperature limit for exposures long enough to reflect metabolic acclimation and optimum ecological performance must lie somewhere between the physiological optimum and the ultimate upper incipient lethal temperature.

Examination of literature on physiological optima (swimming, metabolic rate, temperature preference, growth, natural distribution, and tolerance) of several species has yielded an apparently sound theoretical basis for estimating an upper temperature limit for long-term exposure. The most sensitive function for which data are available appears to be growth rate.

A temperature that is one-third of the range between the optimum temperature for growth and the ultimate incipient lethal temperature can be calculated by the formula:

$$\text{Optimum temp for growth} + \frac{\text{Ultimate incipient lethal temp} - \text{optimum temp for growth}}{3}$$

This formula offers a practical method for obtaining allowable limits, while retaining as its scientific basis the requirements of preserving adequate rates of growth. This formula was used to calculate the summer growth (on a monthly basis) criteria in Table 1.

The criterion for a specific location would be determined by the most sensitive life stage or the sensitive important species likely to be present in that location at that time. Since many fishes have restricted habitats (e.g., specific depth zones) at many life stages, the thermal criterion must be applied to the proper zone. There is field evidence that fish avoid localized areas of unfavorably warm water. This has been demonstrated both in lakes where coldwater fish normally evacuate warm shallows in summer

and at power station heated plumes. In most large bodies of water there are both vertical and horizontal thermal gradients that mobile organisms can follow to avoid unfavorable high (or low) temperatures. The summer maxima must apply to restricted local habitats such as lake hypolimnia or thermoclines, that provide important summer sanctuary areas for coldwater species. Any avoidance of a warm area within the normal seasonal habitat of the species will mean that less area of the water body is available to support the population and that production may be reduced. Such reduction should not interfere with biological communities or populations of important species to a degree which is damaging to the ecosystem or other beneficial uses. Non-mobile organisms that must remain in the warm zone will probably be the limiting organisms for that location. Any upper limiting temperature criteria must be applied carefully with understanding of the population dynamics of the species in question in order to establish both local and regional requirements.

Maximum Weekly Average Temperature for Winter

Although artificially produced temperature elevations during winter months may actually bring the temperature closer to optimum or preferred temperature for important species, and therefore attract fish, metabolic acclimation to these higher levels can preclude safe return of the organism to ambient temperatures should the artificial heating suddenly cease or the organism be driven from the heated area. The lower limit of the range of thermal tolerance of important species must, therefore, be maintained at the normal seasonal ambient temperatures throughout cold seasons. This can be accomplished by limitations on temperature elevations in such areas as discharge canals and mixing zones where organisms may reside, or by insuring

that maximum temperatures occur only in areas not accessible to important aquatic life for lengths of time sufficient to allow metabolic acclimation. Such inaccessible areas would include the high-velocity zones of diffusers or screened discharge channels. This reduction of maximum temperatures would not preclude use of slightly warmed areas as sites for intense winter fisheries.

This consideration may be important in some regions at times other than in winter. The Great Lakes, for example, are susceptible to rapid changes in elevation of the thermocline in summer which may induce rapid decreases in shoreline temperatures (upwelling). Fish acclimated to exceptionally high temperatures in discharge canals may be killed or severely stressed without changes in power plant operations.

Some numerical values for acclimation temperatures and lower limits of tolerance ranges (lower incipient lethal temperatures) for several species are given in Appendix A. Lower winter temperature is necessary for some species such as yellow perch for egg maturation and lake whitefish for egg incubation.

Figure 1 is a nomograph that demonstrates the relationship between the maximum weekly average temperature acceptable in heated plumes and different ambient temperatures. The nomograph was calculated using lower incipient lethal temperature data that would, after applying the 2° C safety factor, ensure protection against partial lethality for most fish species for which there are data (22). At an acclimation (heated plume) temperature of 10° C (50° F) or less, warm water fishes can tolerate a drop in temperature to any lower ambient temperature. Conversely (see Fig. 1), whenever the ambient

temperature is less than 2.5° C (37° F), the heated plume may be as warm as 10° C (50° F). However, trout and salmon cannot withstand comparable temperature declines and the thermograph should be used down to an ambient temperature of 0° C (32° F). At this temperature a maximum plume temperature of 5° C (41° F) is permissible.

The maximum weekly average temperatures during the winter months are applicable to the heated plume rather than the receiving water since the principal concern for most fish at that time is to protect against excessive rapid decline in temperature. At the time that the earliest spawning should occur, the appropriate maximum weekly average temperature for the receiving water must be applied again. If species similar to yellow perch or lake whitefish are to be protected, a maximum weekly average temperature in the receiving water during the winters should be necessary as well as the limitation in the plumes.

Short-term Exposure to Extreme Temperature

To protect aquatic life and yet allow other uses of the water, it is essential to know the lengths of time organisms can survive extreme temperatures (i.e., temperatures that exceed the 7-day incipient lethal temperature). The length of time that 50 percent of a population will survive temperature above the incipient lethal temperature can be calculated from a regression equation of experimental data as follows:

$$\log (\text{time in min.}) = a + b (\text{Temp. in } ^\circ\text{C})$$

where a and b are intercept and slope, respectively, which are characteristics of each acclimation temperature for each species (22). In some cases the

time-temperature relationship is more complex than the semilogarithmic model given above. This equation, however, is the most applicable, and is generally accepted by the scientific community (5). Caution is recommended in extrapolating beyond the data limits of the original research. Thermal resistance may be diminished by the simultaneous presence of toxicants or other debilitating factors. The most accurate predictability can be derived from data collected using water from the site under evaluation.

It is clear that adequate data are available for only a small percentage of aquatic species, and additional research is necessary. Thermal resistance information should be obtained locally for critical areas to account for simultaneous presence of toxicants or other debilitating factors, a consideration not reflected in the Appendix data.

The resistance time equation discussed earlier was used to calculate tolerance limits for many species of fish for several time intervals up to 10,000 minutes. The results of these calculations revealed a uniform relationship between these species that would permit establishing maximum acceptable temperatures for spring, summer, and fall that would protect fish against lethal conditions when subjected to occasional temperature levels exceeding the maximum weekly average temperature during these seasons. These limits, applicable to the receiving water, are summarized in Table 1 and are based on the 24-hour median tolerance limit, minus the 2° C (3.6° F) safety factor discussed earlier using the maximum weekly average temperature as the acclimation temperature.

Since these temperatures exceed those permitting satisfactory, albeit sub-optimal growth, unnatural excursions above the maximum weekly average

temperature to the maximum temperature should be permitted only in extreme instances and then only for short time periods.

A procedure has been developed and discussed for the evaluation of specific thermal discharge sites using a rearrangement of the resistance-time equation (22). This useful procedure allows the summation of specific effects on aquatic organisms during passage through condensers, discharge canals and heated plumes.

During the spawning season short-term maxima determined using the resistance time equation will protect the spawning population from lethal temperatures. However, spawning and egg incubation temperature requirements are more restrictive (lower) and these biological processes would not be protected by those maxima. The upper temperature limits for successful spawning and egg incubation for a given fish species are essentially the same and these limits are the recommended short-term maxima during the spawning season (Table 2).

Reproduction and Development

The sequence of events relating to gonad development, spawning migration, release of gametes, development of the egg and embryo, and commencement of independent feeding represents one of the most complex phenomena in nature, both for fish (23) and invertebrates (6). These events are generally the most thermally sensitive of all life stages. The erratic sequence of failures and successes of different year classes of lake fish attests to the unreliability of natural conditions for providing optimum reproduction each year.

Uniform elevations of temperature by a few degrees during the spawning period, while maintaining short-term temperature cycles and seasonal thermal

patterns, appear to have little overall effect on the reproductive cycle of resident aquatic species, other than to advance the timing for spring spawners or delay it for fall spawners. Such shifts are often seen in nature, although no quantitative measurements of reproductive success have been made in this connection. For example, thriving populations of many fishes occur in diverse streams of the Tennessee Valley in which the date of spawning may vary in a given year by 22 to 65 days. Examination of the literature shows that shifts in spawning dates by nearly one month are common in natural waters throughout the U. S. Populations of some species at the southern limits of their distribution are exceptions - the lake whitefish (Coregonus clupeaformis) in Lake Erie that require a prolonged, cold incubation period (24) and species such as yellow perch (Perca flavescens) that require a long chill period for egg maturation prior to spawning (25).

Highly mobile species that depend upon temperature synchrony among widely different regions or environments for various phases of the reproductive or rearing cycle (e.g., anadromous salmonids or aquatic insects) could be faced with dangers of dis-synchrony if one area is warmed, but another is not. Poor long-term success of one year class of Fraser River (British Columbia) sockeye salmon (Oncorhynchus nerka) was attributed to early (and highly successful) fry production and emigration during an abnormally warm summer followed by unsuccessful, premature feeding activity in the cold and still unproductive estuary (26).

Changes in Structure of Aquatic Communities

Significant change in temperature or in thermal patterns over a period of time may cause some change in the composition of aquatic communities

(i.e., the species represented and the numbers of individuals in each species). Allowing temperature changes to significantly alter the community structure in natural waters may be detrimental, even though species of direct importance to man are not eliminated.

Alteration of aquatic communities by the addition of heat may occasionally result in growths of nuisance organisms provided that other environmental conditions essential to such growths (e.g., nutrients) exist.

Data on temperature limits or thermal distributions in which nuisance growths will be produced are not presently available due in part to the complex interactions with other growth stimulants. There is not sufficient evidence to say that any temperature increase will necessarily result in increased nuisance organisms. Careful evaluation of local conditions is required for any reasonable prediction of effect.

EXAMPLE

The nuances of developing freshwater aquatic life criteria for temperature can best be understood by an example (Table 3). Tables 1 and 2 and Figure 1 and the Appendix are the principal sources for the criteria. The following additional information about the specific environment to which the criteria will apply is needed.

1. Species to be protected by the criteria. (In this example, they are bluegill, largemouth bass, and white crappie).
2. Local spawning seasons for these species. (Bluegill - May to July; white crappie - April to June; largemouth bass - May to July).
3. Normal seasonal rise in temperature during the spawning season. (Since spawning may occur over a period of a few months and only a single

maximum weekly average temperature for optimal spawning is given for a species (Table 2), one would use that optimal temperature for the middle month of the spawning season. In a normal season the criterion for the first month of a three-month spawning season should be below the maximum weekly average temperature for spawning for the species to be protected, and the last month should be above this temperature. Such a pattern should simulate the natural seasonal rise .

4. Normal ambient winter temperature. (In this case it is 5° C (41° F) in December and January and 10° C (50° F) in November, February, and March. These will be used to determine permissible plume temperatures in the winter (Figure 1).)

5. The principal growing season for these species. (In this example it is July through September. Criteria in Table 1 will be used).

6. Any local extenuating circumstances. (If certain non-fish species or food organisms are especially sensitive and thermal requirement data are available, these data should be used as well as the criteria considered for the fish species).

In some instances there will be insufficient data to determine each necessary criterion for each species (Table 3). One must make estimates based on any available data and by extrapolation from data for species for which there are adequate data. For instance, if the above example had included the white bass for which only the maximum weekly average temperature for spawning is given, one would of necessity have to estimate that its summer growth criterion would approximate that for the white crappie which has a similar spawning requirement.

The choice of desirable fish species is very critical. Since in this example the white crappie is the most temperature sensitive of the three species, the maximum weekly average temperature for summer growth is based on the white crappie. Consequently, the criteria would result in lower than optimal conditions for the bluegill and largemouth bass. An alternate approach would be to develop criteria for the single most important species even if the most sensitive is not well protected. The choice is a socioeconomic one.

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TABLE 1

Maximum Weekly Average Temperatures for Growth and Short-Term
Maxima for Survival for Juveniles and
Adults During the Summer
(Centigrade and Fahrenheit)^a

<u>Species</u>	<u>Growth</u>	<u>Maxima^a</u>
Atlantic Salmon	20 (68)	23 (73)
Bighorn Buffalo	-	-
Black Crappie	27 (81)	-
Bluegill	29 (84)	32 (90)
Brook Trout	19 (66)	23 (73)
Carp	-	-
Channel Catfish	32 (90)	36 (97)
Coho Salmon	18 (64)	24 (75)
Emerald Shiner	30 (86)	31 (88)
Freshwater Drum	-	-
Lake Herring (Cisco)	17 (63) ^b	25 (77)
Largemouth Bass	32 (90)	34 (93)
Northern Pike	28 (82)	30 (86)
Rainbow Trout	19 (66)	24 (75)
Sauger	25 (77)	-
Smallmouth Bass	29 (84)	-
Smallmouth Buffalo	-	-
Sockeye Salmon	18 (64)	22 (72)
Striped Bass	-	-
Threadfin Shad	-	-
White Bass	-	-
White Crappie	27 (81)	-
White Sucker	28 (82) ^b	-
Yellow Perch	22 (72)	29 (84)

^aBased on 24-hour median lethal limit minus 2° C (3.6° F) and acclimation at the maximum weekly average temperature for summer growth.

^bBased all or in part on data for larvae.

TABLE 2

Maximum Weekly Average Temperature for Spawning and Short-term
 Maxima for Embryo Survival During the Spawning Season
 (Centigrade and Fahrenheit).

<u>Species</u>	<u>Spawning</u>	<u>Maximum</u>
Atlantic Salmon	5 (41)	7 (45)
Bigmouth Buffalo	17 (63)	27 (81)
Black Crappie	-	-
Bluegill	25 (77)	34 (93)
Brook Trout	9 (48)	13 (55)
Carp	21 (70)	26 (79)
Channel Catfish	27 (81)	29 (84)
Coho Salmon	10 (50)	13 (55)
Emerald Shiner	23 (73)	27 (81)
Freshwater Drum	21 (70)	26 (79)
Lake Herring (Cisco)	3 (37)	8 (46)
Largemouth Bass	21 (70)	27 (81)
Northern Pike	12 (54)	19 (66)
Rainbow Trout	9 (48)	13 (55)
Sauger	10 (50)	21 (70)
Smallmouth Bass	17 (63)	25 (77)
Smallmouth Buffalo	17 (63)	21 (70)
Sockeye Salmon	10 (50)	13 (55)
Striped Bass	18 (64)	24 (75)
Threadfin Shad	18 (64)	34 (93)
White Bass	19 (66)	24 (75)
White Crappie	18 (64)	23 (73)
White Sucker	10 (50)	21 (70)
Yellow Perch	12 (54)	20 (68)

I
TABLE 3

Criteria Developed for Example^a
(Centigrade and Fahrenheit)

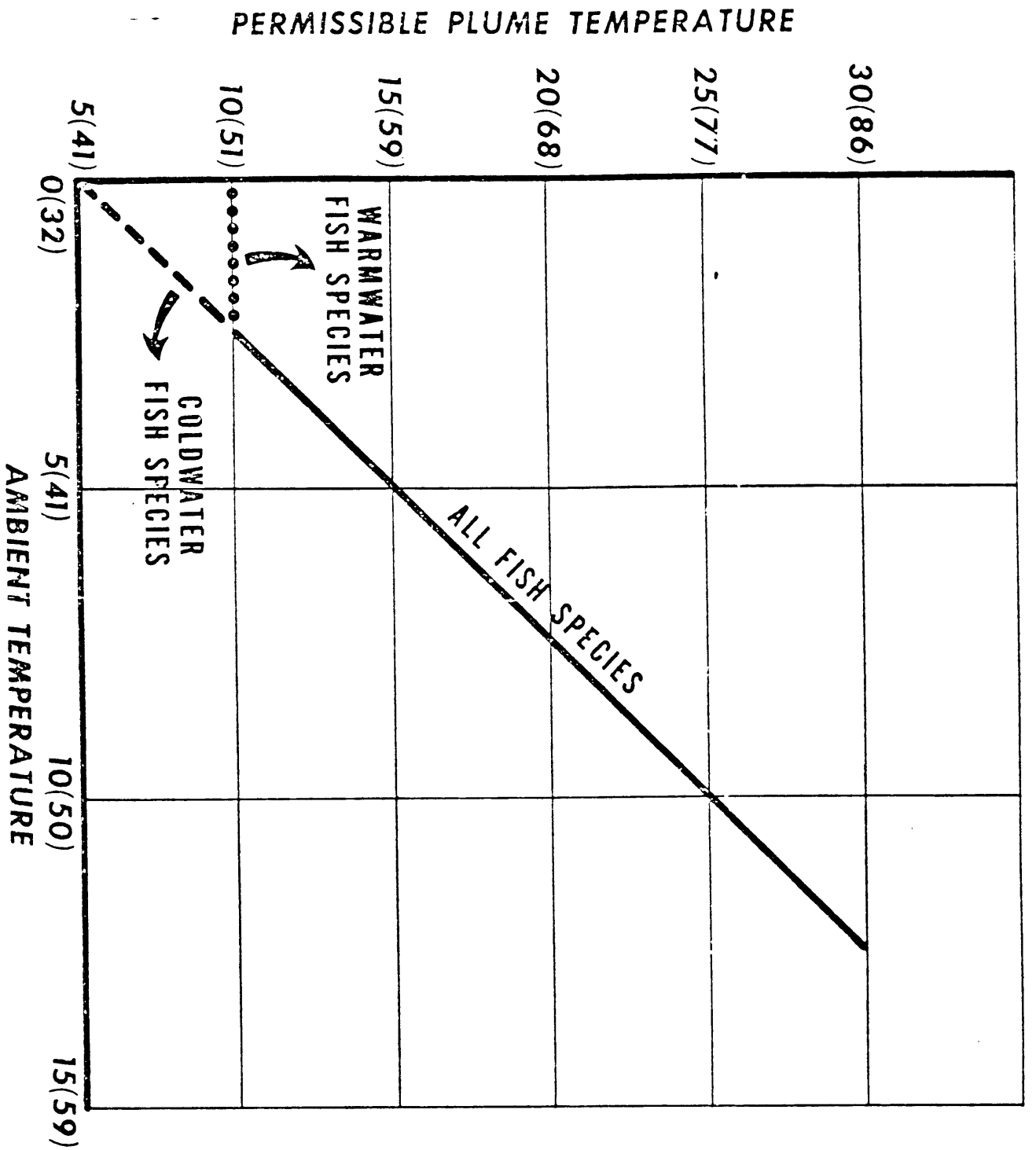
<u>Month</u>	<u>Maximum Weekly Average Temperature</u>		<u>Decision Basis</u>
	<u>Receiving Water</u>	<u>Heated Plume</u>	
JAN	- ^a	15 (59)	Protection against temperature drop
FEB	- ^a	25 (77)	Protection against temperature drop
MAR	- ^a	25 (77)	Protection against temperature drop
APR	18 (64)	-	White crappie spawning
MAY	21 (70)	-	Largemouth bass spawning
JUN	25 (77)	-	Bluegill spawning and white crappie growth
JUL	27 (80)	-	White crappie growth
AUG	27 (80)	-	White crappie growth
SEP	27 (80)	-	White crappie growth
OCT	21 (70)	-	Normal gradual seasonal decline
NOV	- ^a	25 (77)	Protection against temperature drop
DEC	- ^a	15 (59)	Protection against temperature drop

	<u>Short-Term Maximum</u>	<u>Decision Basis</u>
JAN	-	
FEB	-	
MAR	-	
APR	26 (79)	Bluegill ^b survival (estimated)
MAY	29 (84)	Bluegill ^b survival (estimated)
JUN	32 (90)	Bluegill ^b survival
JUL	32 (90)	Bluegill ^b survival
AUG	32 (90)	Bluegill ^b survival
SEP	32 (90)	Bluegill ^b survival
OCT	29 (84)	Bluegill ^b survival (estimated)
NOV	-	
DEC	-	

^aIf a species had required a winter chill period for gamete maturation or egg incubation, receiving water criteria would also be required.

^bNo data available for the slightly more sensitive white crappie.

FIGURE 1. NOMOGRAPH TO DETERMINE THE MAXIMUM WEEKLY AVERAGE TEMPERATURE OF PLUMES FOR VARIOUS AMBIENT TEMPERATURES, °C (°F).



FISH TEMPERATURE DATA SHEET

Species: Atlantic salmon Salmo salar

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper	<u>5</u>	<u> </u>	<u>22*</u>	<u> </u>	<u>1</u>
	<u>6</u>	<u>22</u>	<u> </u>	<u> </u>	<u>1</u>
	<u>10</u>	<u> </u>	<u>23*</u>	<u> </u>	<u>1</u>
	<u>20</u>	<u> </u>	<u>23 *</u>	<u> </u>	<u>1</u>
Lower	<u>27.5</u>	<u> </u>	<u>27.5</u>	<u> </u>	<u>10</u>
	<u> </u>	<u> </u>	<u>*30 days after hatch</u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
II. Growth: ^{1/}	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u> </u>	<u> </u>
Optimum and	<u> </u>	<u>16-18</u>	<u> </u>	<u> </u>	<u>4</u>
[range ^{2/}]	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
III. Reproduction:	<u>optimum</u>	<u>range</u>	<u>month(s)</u>	<u> </u>	<u> </u>
Migration	<u>adults 23</u>	<u>or less, smolt 10</u>	<u>or less</u>	<u> </u>	<u>7</u>
Spawning	<u> </u>	<u>5-6(9)</u>	<u>Oct-Dec(8)</u>	<u> </u>	<u>8,9</u>
Incubation and hatch	<u> </u>	<u>0.5-7</u>	<u> </u>	<u> </u>	<u>3</u>
IV. Preferred:	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u> </u>
	<u>4</u>	<u>14(2)</u>	<u> </u>	<u> </u>	<u>2</u>
	<u>Summer</u>	<u> </u>	<u>17(5)</u>	<u>14-16(6)</u>	<u>5,6</u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Atlantic salmon

References

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FISH TEMPERATURE DATA SHEET

Species: Bigmouth buffalo, Ictiobus cyprinellus

	<u>acclimation</u> <u>temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u>data</u> <u>source</u> ^{3/}
I. Lethal threshold:					
Upper					
Lower					
II. Growth: ^{1/}					
Optimum and					
[range ^{2/}]					
III. Reproduction:					
Migration					
Spawning	<u>17</u>	<u>14-27</u>	<u>Apr-June</u>	<u>1, 2, 3, 4, 6</u>	
Incubation and hatch		<u>14-17</u>		<u>2, 5, 6</u>	
IV. Preferred:					
	<u>Summer</u>			<u>31-34*</u>	<u>7</u>
				<u>*Ictiobus sp.</u>	
				<u>field</u>	

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Bigmouth buffalo

References

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FISH TEMPERATURE DATA SHEET

Species: Black crappie, Pomoxis nigromaculatus

	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u>data source</u> ^{3/}
I. Lethal threshold:					
Upper					
	29		33*		2
Lower			*Ultimate incipient level		
II. Growth: ^{1/}		<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
Optimum and			22-25		2
[range ^{2/}]			(11-30)*		2
			*limits of zero growth		
III. Reproduction:	<u>optimum</u>	<u>range</u>	<u>month(s)</u>		
Migration					
Spawning		14-18 (4)*	Mar(4)-July(3)		3,4
Incubation and hatch					
		*begin spawning			
IV. Preferred:	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
	Summer	13-20(5)		24-34(1)	1,5

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Black crappie

References

1. Neill, W. H., J. J. Magnuson and G. G. Chipman. 1972. Behavioral thermoregulation by fishes - new experimental approach. Science 176 (4042:1443).
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FISH TEMPERATURE DATA SHEET

Species: Bluegill, *Lepomis macrochirus*

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper	15(2), 12(8)		27(8)	31 (2)	2,8
	20			32	2
	25(2), 26(8)		36(8)	33 (2)	2,8
	30			34	2
	33		37		8
Lower	15(2), 12(8)		3 (8)	3 (2)	2,8
	20			5	2
	25(2), 26(8)		10 (8)	7 (2)	2,8
	30			11	2
	33		15		8
II. Growth: ^{1/}		larvae	juvenile	adult	
Optimum and				24-27(3)	3
[range ^{2/}]				(16(1)-30(4))	1,4
III. Reproduction:	optimum	range	month(s)		
Migration					
Spawning	25(5)	19(5)-32(6)	Apr-Aug.		1,5,6
Incubation and hatch	22-24	22-34	(1)		8
IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
			32		9

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Bluegill sunfish

References

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FISH TEMPERATURE DATA SHEET

Species: Brook trout Salvelinus fontinalis

	<u>acclimation</u> <u>temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u>data</u> <u>source</u> ^{3/}
I. Lethal threshold:	<u>3</u>		<u>23</u>		<u>3</u>
Upper	<u>11</u>		<u>25</u>		<u>3</u>
	<u>12</u>	<u>20*, 25**</u>			<u>2</u>
	<u>15</u>		<u>25</u>		<u>3</u>
	<u>20</u>		<u>25</u>		<u>3</u>
	<u>25</u>		<u>25</u>		<u>3</u>
Lower		<u>*Newly hatched</u>			
		<u>**Swimup</u>			
II. Growth: ^{1/}		<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
Optimum and		<u>12-15(2)</u>		<u>16(1)</u>	<u>1,2</u>
[range ^{2/}]		<u>(7-18)(2)</u>		<u>(10-19)(1)</u>	<u>1,2</u>
III. Reproduction:	<u>optimum</u>	<u>range</u>	<u>month(s)</u>		
Migration					
Spawning	<u><9</u>	<u>-12</u>	<u>Sept.-Nov.</u>		<u>1</u>
Incubation and hatch	<u>6</u>	<u>-13</u>			<u>1</u>
IV. Preferred:	<u>acclimation</u> <u>temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
			<u>14-19*</u>		<u>4</u>
			<u>*age not given</u>		

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).^{2/} As reported or to 50% of optimum if data permit.^{3/} List sources on back of page in numerical sequence.

Brook trout

References

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FISH TEMPERATURE DATA SHEET

Species: Carp, *Cyprinus carpio*

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper	<u>20</u>	<u> </u>	<u>31-34*</u>	<u> </u>	<u>3</u>
	<u>26</u>	<u> </u>	<u>36*</u>	<u> </u>	<u>3</u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
Lower	<u> </u>	<u> </u>	<u>*24 hr. TL₅₀</u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
II. Growth: ^{1/}	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>		
Optimum and	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
[range ^{2/}]	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
III. Reproduction:	<u>optimum</u>	<u>range</u>	<u>month(s)</u>		
Migration	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
Spawning	<u>19-23(2)</u>	<u>16(4)-26(1)</u>	<u>Mar-Aug(5)</u>	<u>2,4,5</u>	
Incubation and hatch	<u> </u>	<u>17-22 (7)</u>	<u> </u>	<u>7</u>	
	<u>Abnormal</u>	<u>larvae after 35° shock of embryo</u>	<u> </u>	<u>1</u>	
IV. Preferred:	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
	<u>25-35(6)</u>	<u> </u>	<u>31-32(6)</u>	<u> </u>	<u>6</u>
	<u>Summer</u>	<u> </u>	<u> </u>	<u>33-35</u>	<u>8</u>
	<u>10</u>	<u> </u>	<u>17</u>	<u> </u>	<u>6</u>

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Carp

References

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FISH TEMPERATURE DATA SHEET

Species: Channel catfish, Ictalurus punctatus

	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u>data source</u> ^{3/}
I. Lethal threshold:					
Upper	<u>15</u>	<u>31(3)*</u>		<u>30(2)</u>	<u>2,3</u>
	<u>25</u>		<u>35(1)</u>	<u>33(2)</u>	<u>1,2</u>
	<u>30</u>		<u>37</u>		<u>1</u>
	<u>35</u>		<u>38</u>		<u>1</u>
		*No acclimation temperature given			
Lower	<u>15</u>			<u>0</u>	<u>2</u>
	<u>20</u>			<u>0</u>	<u>2</u>
	<u>25</u>			<u>0</u>	<u>2</u>
II. Growth: ^{1/}		<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
Optimum and		<u>29-30(3)</u>	<u>28-30(10)</u>		<u>3,10</u>
[range ^{2/}]		<u>(27-31)(3)</u>	<u>(22-34)(4)</u>		<u>3,4</u>
III. Reproduction:	<u>optimum</u>	<u>range</u>	<u>month(s)</u>		
Migration					
Spawning	<u>27(5)</u>	<u>21-29(5)</u>	<u>Apr-July(6)</u>		<u>5,6</u>
Incubation and hatch	<u>22(8)</u>	<u>18(7)-29(5)</u>			<u>5,7,8</u>
IV. Preferred:	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
	<u>Summer</u>			<u>30-32*</u>	<u>9</u>
				<u>*field</u>	

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).^{2/} As reported or to 50% of optimum if data permit.^{3/} List sources on back of page in numerical sequence.

Channel catfish

References

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FISH TEMPERATURE DATA SHEET

Species: Cisco-(Lake herring), Coregonus artedii

	<u>acclimation</u> <u>temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u>data</u> <u>source</u> ^{3/}
I. Lethal threshold:	2(3), 3(2)	20(2)	20(3)	20(4,6)*	2,3,4,6
Upper	5(3), <10(5)		22(3)	<24(5)	3,5
	>13		26		3
	20		26		3
	25		26		3
				*accl. temp. unknown	
Lower	2		3		3
	5		.5		3
	10		3		3
	20		5		3
	25		10		3
II. Growth: ^{1/}	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>		
Optimum and	16				2
[range ^{2/}]	(13-18)				2
III. Reproduction:	<u>optimum</u>	<u>range</u>	<u>month(s)</u>		
Migration	To spawning grounds at ≈ 5				7
Spawning	3	1-5	Nov-Dec		7,8,9
Incubation and hatch	6(1)	2-8(1)	Apr-May (8-9)		1,8,9
IV. Preferred:	<u>acclimation</u> <u>temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
				13	6

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Cisco

References

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FISH TEMPERATURE DATA SHEET

Species: Coho salmon, *Oncorhynchus kisutch*

I. Lethal threshold:	acclimation	larvae	juvenile	adult	data source ^{3/}
	temperature				
Upper	5		21		1
	10		21	21* (3)	1,3
	15		24		1
	20		25		1
	23		25		1
Lower				*Accl. temp	unknown
	5		0.2		1
	10		2		1
	15		3		1
	20		5		1
	23		6		1
II. Growth: ^{1/}	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>		
Optimum and		15*			2
[range ^{2/}]		(5-17)			6
		*unlimited food			
III. Reproduction:	<u>optimum</u>	<u>range</u>	<u>month(s)</u>		
Migration		7-16 (5)			5
Spawning		7-13 (3)	Fall		3
Incubation and hatch					
IV. Preferred:	<u>acclimation</u> <u>temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
	Winter			13	4

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).^{2/} As reported or to 50% of optimum if data permit.^{3/} List sources on back of page in numerical sequence.

Coho salmon

References

1. Brett, J. R. 1952. Temperature tolerance in young pacific salmon, genus Oncorhynchus. J. Fis. Res. Bd. Can. 9:265-323.
2. Great Lakes Research Laboratory, 1973. Growth of Lake trout in the laboratory. Progress in Sport Fishery Research. 1971. USDI, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife.
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6. Averett, R. C. 1968. Influence of temperature on energy and material utilization by juvenile coho salmon. Ph.D. Thesis, Oregon State Univ.

FISH TEMPERATURE DATA SHEET

Species: Emerald Shiner, *Notropis atherinoides*

I. Lethal threshold:	acclimation	larvae	juvenile	adult	data source ^{3/}
	temperature				
Upper	5		22-23		1
	10		27		1
	15		29		1
	20		31		1
	25		31		1
Lower					
	15		2		1
	20		5		1
II. Growth: ^{1/}		larvae	juvenile	adult	
	Optimum and		29		2
	[range ^{2/}]		(24-31)		2
III. Reproduction:		optimum	range	month(s)	
	Migration				
	Spawning		20(3)-27(6)	May-Aug(1)	1,3,5,6
	Incubation and hatch			(5)	
IV. Preferred:	acclimation	larvae	juvenile	adult	
	temperature				
	Summer			25*	3
	Winter			27*	4

*unknown age

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).^{2/} As reported or to 50% of optimum if data permit.^{3/} List sources on back of page in numerical sequence.

Emerald shiner

References

1. Carlander, R. D. 1969. Handbook of freshwater fishery biology. Vol. 1, Iowa State Univ. Press, Ames, Iowa.
2. McCormick, J. H. and C. F. Kleiner. 1970. Effects of temperature on growth and survival of young-of-the-year emerald shiners (Notropis atherinoides). Unpublished data, National Water Quality Laboratory, Duluth, Minnesota.
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4. Wapora, Inc. for the Ohio Electric Utilities Inst. 1971. The effect of temperature on aquatic life in the Ohio River. Final Report.
5. Flittner, G. A. 1964. Morphometry and life history of the emerald shiner, Notropis atherinoides Rafinesque. Ph.D. Thesis, Univ. of Mich.
6. Gray, J. W., 1942. Studies on Notropis atherinoides atherinoides Rafinesque in the Bass Islands Region of Lake Erie. Master's Thesis, Ohio State Univ.

FISH TEMPERATURE DATA SHEET

Species: Freshwater drum, Aplodinotus grunniens

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____
Lower	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____
	_____	_____	_____	_____	_____
II. Growth: ^{1/}					
Optimum and					
[range ^{2/}]					
III. Reproduction:					
Migration					
Spawning					
Incubation and hatch					
IV. Preferred:					

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Freshwater drum

References

1. Wrenn, B. B. 1969. Life history aspects of smallmouth buffalo and freshwater drum in Wheeler Reservoir, Alabama. Proc. 22nd Ann. Conf. S. E. Assoc. Game and Fish Comm., 1968. p. 479-495.
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7. Gammon, J. R. 1973. The effect of thermal inputs on the populations of fish and macroinvertebrates in the Wabash River. Tech. Rept. 32. Purdue Univ. Water Resources Research Center.

FISH TEMPERATURE DATA SHEET

Species: Largemouth bass, Micropterus salmoides

I. Lethal threshold:		acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper		20		33		1
		25		35		1
		30		36		1
		35		36		1
Lower		20		5		1
		25		7		1
		30		11		1
II. Growth: ^{1/}		larvae	juvenile	adult		
Optimum and [range ^{2/}]		27	30(3)			2,8
		(20-30)	23-31(8)			2,8
III. Reproduction:		optimum	range	month(s)		
Migration						
Spawning		21(4)	16-27(4)	Apr-June(3) Nov-May(4)		3,4
Incubation and hatch		20(5)	13(5)-26(9)			5,6,9
IV. Preferred:		acclimation temperature	larvae	juvenile	adult	
				30-32*		7
						*season not given

- 1/ As reported or net growth (growth in wt. minus wt. of mortality).
- 2/ As reported or to 50% of optimum if data permit.
- 3/ List sources on back of page in numerical sequence.

Largemouth bass

References

1. Hart, J. S. 1952. Geographic variations of some physiological and morphological characters in certain freshwater fish. Univ. Toronto Biological Series No. 60.
2. Strawn, Kirk. 1961. Growth of largemouth bass fry at various temperatures. Trans. Amer. Fish. Soc., 90:334-335.
3. Kramer, R. H. and L. L. Smith, Jr. 1962. Formation of year class in largemouth bass. Trans. Amer. Fish. Soc., 91:29-41.
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FISH TEMPERATURE DATA SHEET

Species: Northern pike, *Esox lucius*

	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u>data source</u> ^{3/}
I. Lethal threshold:					
Upper	<u>18</u>	<u>25,28*</u>			<u>2</u>
	<u>25</u>		<u>32</u>		<u>1</u>
	<u>27</u>		<u>33</u>		<u>1</u>
	<u>30</u>		<u>33**</u>		<u>1</u>
		*At hatch and free swimming, respectively			
Lower		**Ultimate incipient level			
	<u>18</u>	<u>3*</u>			<u>2</u>
		*At hatch and free swimming			
II. Growth: ^{1/}	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>		
Optimum and	<u>21</u>	<u>26</u>			<u>2</u>
[range ^{2/}]	<u>(18-26)</u>				<u>2</u>
III. Reproduction:	<u>optimum</u>	<u>range</u>	<u>month(s)</u>		
Migration					
Spawning		<u>4(4)-19(3)</u>	<u>Feb-June (5)</u>		<u>3,4,5</u>
Incubation and hatch	<u>12</u>	<u>7-19</u>			<u>2</u>
IV. Preferred:	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	
			<u>24,26*</u>		<u>6</u>

*Grass pickrel and musky, respectively

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Northern pike

References

1. Scott, D. P. 1964. Thermal resistance of pike (Esox lucius L.) muskellunge (E. masquinongy, Mitchell) and their F₁ hybrid. J. Fish. Res. Bd. Canada 21:1043-1049.
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6. Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Bd. Canada 15:607-624.

FISH TEMPERATURE DATA SHEET

Species: Rainbow trout, Salmo gairdneri

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper	18		27		1
	19			21	2
Lower					
II. Growth: ^{1/}					
Optimum and		larvae	juvenile	adult	
[range ^{2/}]			17-19		5
	(3(8) -)				8
III. Reproduction:	optimum	range	month(s)		
Migration					
Spawning		5-13(6)	Nov-Feb(7)		6,7
Incubation and hatch	5-7(9)	5-13(4)	Feb-June(7)		4,9
IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
	Not given		14		3

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Rainbow trout

References

1. Alabaster, J.S. and R. L. Welcomme. 1962. Effect of concentration of dissolved oxygen on survival of trout and roach in lethal temperatures. Nature, Lond. 194(4823), 107-.
2. Coutant, C. C. 1970. Thermal stress of adult coho (Oncorhynchus kisutch) and jack chinook (O. tshawytscha) salmon, and the adult steelhead trout (Salmo gairdnerii) from the Columbia River. AEC BNWL 1508.
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5. Hokanson, K.E.F. and C. F. Kleiner. 1973. Unpublished data, National Water Quality Laboratory, Duluth. Minnesota.
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In: Carlander, K. D. 1969. Handbook of Freshwater Fishery Biology, Vol. 1.
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FISH TEMPERATURE DATA SHEET

Species: Sauger, Stizostedion canadense

	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
I. Lethal threshold:					
Upper	9-21	75-92%*			5
	12		27		5
	18		29		5
	22		30		5
Lower	26	*survival	31		5
	6	0%*			5
		*survival			
II. Growth: ^{1/}	larvae	juvenile	adult		
Optimum and [range ^{2/}]		22			5
III. Reproduction:	optimum	range	month(s)		
Migration					
Spawning	10(4)	6(1)-14(3)	Apr-May(3, 1)	1, 3, 4	
Incubation and hatch	12-15*	10-16*			5
	*Max. egg survival * >50% survival				
IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
				19*	2
	Summer			27-29	6
				*field	

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Sauger

References

1. Nelson, W. R. 1968. Reproduction and early life history of sauger, Stizostedion canadense, in Lewis and Clark Lake. Trans. Amer. Fish. Soc. 97:167-174.
2. Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Bd. Canada. 15:607-624.
3. Hall, G. E. 1972. Personal communication, TVA.
4. Hassler, W. W. 1956. The influence of certain environmental factors on the growth of Norris Reservoir sauger Stizostedion canadense canadense (Smith). Proceedings of Southeastern Assoc. of Game and Fish Commissioners Meeting, 1955. p. 111-119.
5. Smith, L. L. 1973. The effect of temperature on the early life history stages of the Sauger, Stizostedion canadense (Smith). Preliminary data, EPA Grant.
6. Gammon, J. R. 1973. The effect of thermal input on the populations of fish and macroinvertebrates in the Wabash River. Tech. Rept. 32, Purdue Univ. Water Resources Res. Center.

FISH TEMPERATURE DATA SHEET

Species: Smallmouth bass, micropterus dolomieu

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper		33* (9)	35 (3)		9, 3
Lower	15 (3)	*acclimation not given 4 (9)*		2 (3)	3, 9
	18		4		3
	22		7		3
	26		10		3
		*acclimation temperature not given			
II. Growth: ^{1/}		larvae	juvenile	adult	
Optimum and- [range ^{2/}]	28-29 (2)	26 (3)			2, 3
III. Reproduction:	optimum	range	month(s)		
Migration					
Spawning	17-18 (5)	13 (8)-21 (7)	May-July (8)		5, 7, 8
Incubation and hatch					
IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
	Summer			21-27	6
	Winter			>8* (1)-28 (4)	1, 4

*Life stage unknown

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Smallmouth bass

References

1. Munther, G. L. 1968. Movement and distribution of smallmouth bass in the Middle Snake River. Master's Thesis, Univ. Idaho.
2. Peek, F. W. 1965. Growth studies of laboratory and wild population samples of smallmouth bass. Master's thesis, Univ. Arkansas.
3. Horning, W. B. and R. E. Pearson. 1973. Temperature requirements for juvenile smallmouth bass (Micropterus dolomieu): growth and lower lethal temperatures. J. Fish. Res. Bd. Canada (in press).
4. Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Bd. Canada. 15:607-624.
5. Breder, C. M. and D. E. Rosen. 1966. Modes of reproduction in fishes. Natural History Press.
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FISH TEMPERATURE DATA SHEET

Species: Smallmouth buffalo, Ictiobus bubalus

	<u>acclimation temperature</u>	<u>larvae</u>	<u>juvenile</u>	<u>adult</u>	<u>data source</u> ^{3/}
I. Lethal threshold:					
Upper					
Lower					
II. Growth: ^{1/}					
Optimum and					
[range ^{2/}]					
III. Reproduction:					
Migration					
Spawning	<u>17(1,3)</u>	<u>14(1)-21(1,2)</u>	<u>Mar-Jun</u>	<u>1,2,3</u>	
Incubation			<u>(3)</u>		
and hatch		<u>14(1)-21(2)</u>		<u>1,2</u>	
IV. Preferred:					
				<u>31-34*</u>	<u>4</u>

*Ictiobus
sp. field

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Smallmouth buffalo

References

1. Wrenn, W. B. 1969. Life history aspects of smallmouth buffalo and freshwater drum in Wheeler Reservoir, Alabama. Proc. 22nd Ann. Conf. S. E. Assoc. Game & Fish Comm., 1968. pp. 479-495.
2. Walburg, C. H. and W. R. Nelson. 1966. Carp, river carpsucker, smallmouth buffalo and bigmouth buffalo in Lewis and Clark Lake, Missouri River. Bur. Sport Fish. and Wildl. Res. Rep. 69.
3. Walker, M. C. and P. T. Frank. 1952. The propagation of buffalo. Prog. Fish. Cult. 14:129-130.
4. Gammon, J. R. 1973. The effect of thermal input on the populations of fish and macroinvertebrates in the Wabash River. Tech. Rept. 32, Purdue Univ. Water Resources Research Center.

FISH TEMPERATURE DATA SHEET

Species: Sockeye salmon, Oncorhynchus nerka^{a/}

I. Lethal threshold:		acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper		5		22		1
		10		23		1
		15		24		1
		20		25		1
Lower		5		0		1
		10		3		1
		15		4		1
		20		5		1
		23		7		1
II. Growth: ^{1/}		larvae	juvenile	adult		
Optimum and [range ^{2/}]		15(6)	15(2)*			2,6
			10-15			5
*Max. with excess food						
III. Reproduction:		optimum	range	month(s)		
	Migration		7-16			5
	Spawning		7-13	Fall		7
	Incubation and hatch		6-13			4
IV Preferred:		acclimation temperature	larvae	juvenile	adult	
		Summer		15		3

2/ As reported or net growth (growth in wt. minus wt. of mortality).

2/ As reported or to 50% of optimum if data permit.

3/ List sources on back of page in numerical sequence.

a/ Data for sea-run Sockeye, not Kokanee

Sockeye Salmon

References

1. Brett, J. R. 1952. Temperature tolerance in young pacific salmon, genus, Oncorhynchus. J. Fis. Res. Bd. Can. 9:265-323.
2. Griffiths, J. S. and D. F. Alderdice. 1972. Effects of acclimation and accute temperature experience on the swimming speed of juvenile coho salmon. J. Fish. Res. Bd. Can. 29:251-264.
3. Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Bd. Can. 15:607-624.
4. Combs, B. D. and R. E. Burrows. 1957. Threshold temperatures for the normal development of chinook salmon eggs. Prog. Fish. Cult. 19:3-6.
5. Burrows, R. E. 1963. Water temperature requirements for maximum productivity of salmon. Procaedings of the 12th Pacific N. W. Symposium on Water Poll. Res.
6. Shelbourn, J. E. 1973. Effect of temperature and feeding regime on the specific growth rate of sockeye salmon fry (Oncorhynchus nerka) with a consideration of size effect. Jour. Fish. Res. Bd. Can. 30, 1191 No. 8
7. Anonymous. 1971. Columbia River thermal effects study. Vol. 1, Environmental Protection Agency.

FISH TEMPERATURE DATA SHEET

Species: Striped bass, Morone saxatilis

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper					
Lower					
II. Growth: ^{1/}					
Optimum and					
[range ^{2/}]					
III. Reproduction:					
Migration					
Spawning					
Incubation					
and hatch					
IV. Preferred:					

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Striped bass

References

1. Shannon, E. H. 1970. Effect of temperature changes upon developing striped bass eggs and fry. Proc. 23rd Conf. S. E. Assoc. Game and Fish Comm. October 19-22, 1969, pp. 265-274.
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FISH TEMPERATURE DATA SHEET

Species: Threadfin shad Dorosoma petenense

	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
I. Lethal threshold:					
Upper					
Lower					
			9*		1
II. Growth: ^{1/}					
Optimum and					
[range ^{2/}]					
III. Reproduction:					
Migration					
Spawning		14-21(3,4)		Apr-Aug (4)	3,4
Incubation and hatch		23(5)-34(7) 17-27(6)			5,6,7
IV. Preferred:					
				>19	2

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permits.

^{3/} List sources on back of page in numerical sequence.

Threadfin shad

References

1. Strawn, K. 1963. Resistance of threadfin shad to low temperatures. Proc. 17th Ann. Conf. Southeastern Assoc. of Game and Fish Comm. pp. 290-293.
2. Adair, W. D. and D. J. DeMont. 1979. Effects of thermal pollution upon Lake Norman fishes. N. Carolina Wildlife Res. Comm., Div. Inland Fisheries. Summary Report, Fed. Aid Fish Restoration Project F-19-2. 14 p.
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5. Shelton, W. L. 1964. The threadfin shad, Dorosoma petenense (Gunther): Oogenesis, seasonal ovarian changes and observations on life history. Master's Thesis, Oklahoma State Univ. 49 p.
6. Breder, C. M. and D. E. Rosen. 1969. Modes of reproduction in fishes. Natural History Press.
7. Hubbs, C. and C. Bryan. 1974. Maximum incubation temperature of the threadfin shad, Dorosoma petenense. Trans. Amer. Fish Soc. 103:369-371.

FISH TEMPERATURE DATA SHEET

Species: White bass Morone chrysops

I. Lethal threshold:		acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper						
Lower						
		17	14*			3
*% mortality not given						
II. Growth: ^{1/}		larvae	juvenile	adult		
Optimum and			23-24*			4
range ^{2/}]						
*good growth in S.D. reservoir						
III. Reproduction:		optimum	range	month(s)		
Migration						
Spawning			14-24 (north)	Apr-Jul (North)	1	
Incubation			12- (Tenn.)	Mar-May (Tenn)	1	
and hatch		16-17			2	
IV. Preferred:		acclimation temperature	larvae	juvenile	adult	
		Summer			28-30*	5
*Field						

- 1/ As reported or net growth (growth in wt. minus wt. of mortality).
2/ As reported or to 50% of optimum if data permit.
3/ List sources on back of page in numerical sequence.

FISH TEMPERATURE DATA SHEET

Species: White crappie, Pomoxis annularis

I. Lethal threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
Upper					
			33*		5
			*Ultimate incipient level		
Lower					
II. Growth: ^{1/}		larvae	juvenile	adult	
Optimum and			25		5
[range ^{2/}]					
III. Reproduction:	optimum	range	month(s)		
Migration					
Spawning	16-20(6)	14-23(6)	Mar(4)-		
Incubation		18-20(4)*	July(3)		3,4,6
and hatch		*begin spawning			
	Hatch in 24-27-1/2 hrs. at 21-23				2
IV. Preferred:	acclimation temperature	larvae	juvenile	adult	
				28-29	1

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

White crappie

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FISH TEMPERATURE DATA SHEET

Species: White sucker Catostomus commersoni

III. Incubation threshold:	acclimation temperature	larvae	juvenile	adult	data source ^{3/}
	5		26(2)		2
	10	28 (1)*	28(2)		1,2
	15	31 (1)	29(2)		1,2
	20(2), 21(1)	30 (1)	29(2)		1,2
	25		29		2
	25-26		31		3
		*7-day TL50 for swimup			
	20		2-3		2
	21	6*			1
	25		6		1
		*7-day TL50 for swimup			
IV. Growth: ^{1/}	larvae	juvenile	adult		
	27			1	
	(24-27)			1	
V. Reproduction:	optimum	range	month(s)		
	~ 10(5)	~ 4-18(5,6)	Mar-June (2)	2,5,6	
	15	8-21		1	
VI. Preferred:	acclimation temperature	larvae	juvenile	adult	
				19-21	4

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

White sucker

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FISH TEMPERATURE DATA SHEET

Species: Yellow perch Perca flavescens

I. Lethal threshold:	acclimation	larvae	juvenile	adult	data
	temperature				source ^{3/}
Upper	5			21	1
	11(1), 10(4)	10(4)*		25(1)	1,4
	15(1), 19(4)	19(4)*		28(1)	1,4
	25			30*	1
	25	*swim-up		32**	1
Lower				*winter	
				**summer	
	25		4		1
II. Growth: ^{1/}		larvae	juvenile	adult	
Optimum and [range ^{2/}]				13(6)-20(7)	6,7
III. Reproduction:	optimum	range	month(s)		
Migration					
Spawning	12(3)	7(5)-15(3)	Mar-June (3)		3,5
Incubation and hatch	10 up 1°/day to 20	7-20			4
IV. Preferred:	acclimation	larvae	juvenile	adult	
	temperature				
	Winter		22(8)	21(2)	8,2
	Summer		24		2
	24		20-23	18-20	9

^{1/} As reported or net growth (growth in wt. minus wt. of mortality).

^{2/} As reported or to 50% of optimum if data permit.

^{3/} List sources on back of page in numerical sequence.

Yellow perch

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MARINE TEMPERATURE CRITERIA

The philosophy underlying criteria for marine and estuarine cooling water is that volumes shall be minimized to reduce plant passage of planktonic organisms. Accordingly, there shall be no dilution pumping.

- a. The maximum acceptable increase in surface temperatures is 2.2°C (4°F) during fall, winter, and spring.
- b. The maximum acceptable increase in surface temperatures is 1.1°C (2°F) during the summer (defined as July-September north of Long Island and the northern extremity of California; June-September south of those points).
- c. Alteration of characteristic daily temperature cycles in either frequency or amplitude is unacceptable.
- d. Exceeding the following summer maxima is unacceptable:

	<u>Maximum</u>	<u>True Daily Mean*</u>
Tropical Regions (South of Cape Canaveral and Tampa Bay, Florida, Puerto Rico, Pacific tropical islands)	32.2°C (90°F)	30°C (86°F)
Cape Hatteras, N.C. to Cape Canaveral, Florida	32.2°C (90°F)	29.4°C (85°F)
Long Island (south shore) to Cape Hatteras, N.C.	30°C (86°F)	27.8°C (82°F)

*True Daily Mean = the daily average of 24 hourly temperature readings. Data presently are not sufficient to prescribe general upper limits for other regions of the country. Nonetheless, development of ceilings on a case-by-case basis using best available data is recommended.

- e. Rapid temperature decreases associated with plant shutdown are unacceptable when ambient water temperature is less than 15°C (59°F).

RATIONALE

The preceding criteria summarize temperature conditions necessary to protect marine ecosystems and represent constraints which can be

met by using submerged discharge. Volume of the vertical diffusion zone in which temperature criteria do not apply is intended to be minimized by siting on relatively deep and well flushed waters. Near-bottom diffuser discharge should be at a depth which would not only meet summer receiving water criteria at the surface (i.e. a delta 2°F rise) but which also results in a mixing zone without excessive horizontal dimensions. Biologically, loss of surface area is as important as volume considerations in the marine environment. As shallow portions of estuaries are highly productive and represent important nursery areas, shallow water discharge is not recommended.

An instantaneously measured ambient temperature is to serve as the baseline for permissible elevations. Baseline thermal conditions shall be measured at a site in which there is no unnatural thermal addition from any source, which is in reasonable proximity to the power plant, and which has similar hydrography to that of the receiving waters at the discharge point. Measurements shall be made 6 inches below the surface.

Estuarine and coastal communities normally experience diurnal and tidal temperature variations. Laboratory studies have demonstrated that thermal tolerance is enhanced when animals are maintained under a diurnally fluctuating temperature regime rather than at constant temperature (Costlow, 1971). In addition, a daily cyclic regime is protective as it serves to reduce the duration of single exposures of supraoptimal temperatures. This has been observed in the intertidal blue mussel (Mytilus edulis) (Pearce, 1969; Gonzalez, 1972). A mussel bed can tolerate brief exposure to summer low tide temperatures of 29-30°C if it is flooded intermittently by cooler tidal water. In the laboratory, constant exposure to 30°C caused mussel death in 9-12 hours, while 6-hour cyclic exposures from 30 to 25°C were tolerated for over 40 days.

It is also necessary to maintain the natural annual temperature cycle. This should approximate the historical thermal regime under which local biota evolved and indigenous communities developed. Regular thermal events, such as the diurnal cycle and irregular phenomena including

atmospheric frontal passages, are examples of components of this historical regime. These natural heterogeneous temperature patterns must be maintained. A permissible incremental rise over ambient conditions is presently the best approach to define ecologically safe thermal elevations for the marine community.

During late fall, winter, and spring, natural temperature conditions are usually well below critical upper thermal limits for most life functions. More subtle effects of artificial heat on the biota, particularly from a total system standpoint, are not well documented for these seasons. Some marine species, including winter flounder and cod, require periods of cold water temperatures for maintenance of physiological condition, development, reproduction, and survival and growth of eggs and larvae (Rogers, in press; Johansen & Krogh, 1914). The recommended constraint of 2.2°C (4°F) elevation over ambient represents an increase of approximately 50 percent of the range of diurnal fluctuation in temperature commonly observed in well-mixed estuarine waters. The permissible elevation should meet environmental requirements of cold water species. It falls well within the tolerance range of most motile marine organisms passing through a thermal discontinuity. Also protected are benthic or intertidal species confronted with thermal pulses resulting from tidal circulation of warm water.

During summer, natural thermal maxima can occur in magnitude sufficient to cause heat death or emigration by motile forms. This is particularly common in the tropics and warm temperate zones (Vaughan, 1918; Glynn, 1968; Chin, 1961). Natural thermal kills also occur in more northern waters, e.g. a winter flounder kill in Moriches Bay, Long Island, N.Y. (Nichols, 1918). Temperature incremental ceilings are applicable during the period of maximum natural heating when further thermal addition could be deleterious. These increments may be lower than prevailing water temperatures in some coastal embayments for certain periods, yet these are nonetheless times of thermal stress for the marine system. Some organisms continue to populate waters having a warmer daily regime, but thermally sensitive species are absent. Addition of heat from artificial sources at such sites during periods of maximum heating is not appropriate. For these regions of the country where data presently are not sufficient to prescribe general

upper thermal limits, development of ceilings on a case-by-case basis is recommended.

Boundaries for regional ceilings are demarcated by biogeographic provinces. Species composition of the marine system, and most important, responses to elevated temperature, are generally similar within a region. Boundaries of a biotic province are characterized by significant thermal discontinuities. Boundary areas are maintained during summer or winter due to combined forces of current, wind, and coastal geomorphology. On the east coast, Cape Canaveral, Fla., Cape Hatteras, N.C., and Cape Cod, Mass., represent these boundaries. On the west coast, Pt. Conception in southern California marks the limit of warm and cold temperate zones.

Recommended thermal criteria are based on scientific evaluation of best available data. Selected representative data are tabulated below for an array of ecologically diverse marine organisms, grouped by biotic region. Data largely document limitations of thermal addition during summer. Unless otherwise noted, cited studies deal only with summer or warm-acclimated organisms. Results of sublethal effects studies are cited also. Twenty-four hour T_{Lm} (median tolerance limit) data have been adjusted by subtracting 2.2°C to estimate the upper thermal protection limit for the life history stage in question (Mihursky, 1969). Recognized biological variables such as recent environmental history, nutritional state, size, sex, and age are considered for all thermal effects investigations. Likewise, contrasting methods of study are considered.

Normally, thermal effects data derived in one biotic region should not be applied to another. Latitudinally separated populations of widely distributed species may exhibit significant generic variability and usually have experienced different recent environmental histories. The manner in which data relate seasonally to a local temperature regime is illustrated by the Cold Temperate Zone (southern portion) superimposed on the 20-year mean temperature curve of the Pawtuxet River at Solomons, Md. (Figure 1). It should be recognized that mean temperature curves show only the thermal norm, and not short-term extremes which are ecologically the more significant.

Boreal Zone, Atlantic Coast: This region extends from Cape Cod, Mass., to the Gulf of Maine. Insufficient data are available for setting regional temperature limits. Upper limits should be determined on a case-by-case basis using best available data for the site and its environs.

In the boreal region, maintenance of a general temperature regime resembling natural conditions is particularly important during winter months. Some boreal species require periods of uninterrupted low water temperatures to fulfill environmental requirements for successful maturation of sexual products, spawning, and subsequent egg and larval survival. Winter flounder (Pseudopleuronectes americanus) have an upper limit for spawning of 5.5°C (Bigelow and Schroeder, 1953). Spawning occurs during the winter.

Ten °C is the upper thermal limit for Atlantic salmon (Salmo salar) smolt migration to the sea, which normally occurs in June. Twelve °C inhibits maturation of sex products (DeCola, 1970). Development of winter flounder (Pseudopleuronectes americanus) eggs to hatching is reduced 50% at 13°C (Rogers, in press). Blood worm (Glycera americana) spawning is induced when temperatures reach 13°C (Creaser, 1973). Fifteen °C is the upper limit for spawning Atlantic herring (Clupea harangus) (Hela and Laevastu, 1962), and of an amphipod, Psammox nobilis, (Scott, unpublished). In Atlantic herring, there is above normal incidence of a protozoan disease at 15°C (Sinderman, 1965); and at 16°C, there is a prevalence of erythrocyte degeneration (Sherburne, 1973). Field mortality of yellowtail flounder larvae (Limanda ferruginea) was observed at 17.8°C (Colton, 1959). The protection limit for yearling Atlantic herring (48-hr T_{LM} - 2.2°C) is 19.0°C (Brawn, 1960). At 21°C, embryonic development ceases in the amphipod, Gammarus deuben (Steele and Steele, 1969). Above 21.1°C, spores are killed and growth is reduced in the macroalga, Chondrus crispus, which is commercially harvested as Irish moss (Prince & Kingsbury, 1973).

Cold Temperate Zone, Atlantic Coast: Temperature ceilings are particularly critical in the southern portion of this region (south shore of Long Island to Cape Hatteras, N.C.) where enclosed sounds

and large coastal-plain bays and rivers are prevalent. Maximum temperatures should not exceed 30°C (86°F). The true daily mean should not exceed 27.8°C (82°F). Were 30°C to persist for over 4 to 6 hours, appreciable stress or direct mortality would occur among juvenile winter flounder, striped mullet larvae, Atlantic silversides eggs, larvae, and adults; adult northern puffer, adult blue mussel, and adult soft shell clam (Mya arenaria). Specific critical temperatures for these species are detailed in Figure 1. Adult protection limit (TLm - 2.2°C) is 28.8°C for sand shrimp (Crangon septemspinosa) and 30.8°C for opossum shrimp (Neomysis americanus). Both are important food organisms for fish (Mihursky & Kennedy, 1967). Respiration rate is depressed above 30°C in the mole crab (Emerita talpoida) (Edwards & Irving, 1943). At 31.5°C, there is 67% mortality in coot clam (Mulinia lateralis) when exposed for 6 hours (Kennedy, et al, 1974).

A limit of 27.8°C approximates the upper limit for larval growth of the coot clam (27.5°C; Calabrese, 1969) and the upper tolerance limit for soft shell clam adults (28.0°C; Pfitzenmeyer, unpublished). Between 28 and 30°C juvenile amphipods (Corophium insidiosum) leave their tubes and thereby lose natural protection from predation (Gonzalez, 1972). Such elevated temperatures may also have subtle sublethal effects, such as reducing feeding and growth. In the quahog (Mercenaria mercenaria), growth is optimum at 20°C (Ansell, 1968). Growth is inhibited above 24°C in a rock weed (Ascophyllum nodosum) (Southland & Hill, 1970). Prolonged locomotion is markedly reduced at 22°C in the rock crab, Cancer borealis; at 28°C in C. irroratus (Jeffries, 1967). An oyster pathogen (Dermocystidium marinum) proliferates readily only above 25°C (Andrews, 1965).

High temperature will usually elicit avoidance response in fishes. Avoidance is triggered at 29°C in Atlantic menhaden (Brevoortia tyrannus), and at 26.5°C in sea trout (Cynoscion regalis) (Meldrin & Gift, 1971). Breakdown of the avoidance response in striped bass occurs at 30°C (Gift & Westman, 1971). Maximum reported temperature for capture of spotted hake (Urophycis regis) is 24.8°C in Chesapeake Bay (Barans, 1972).

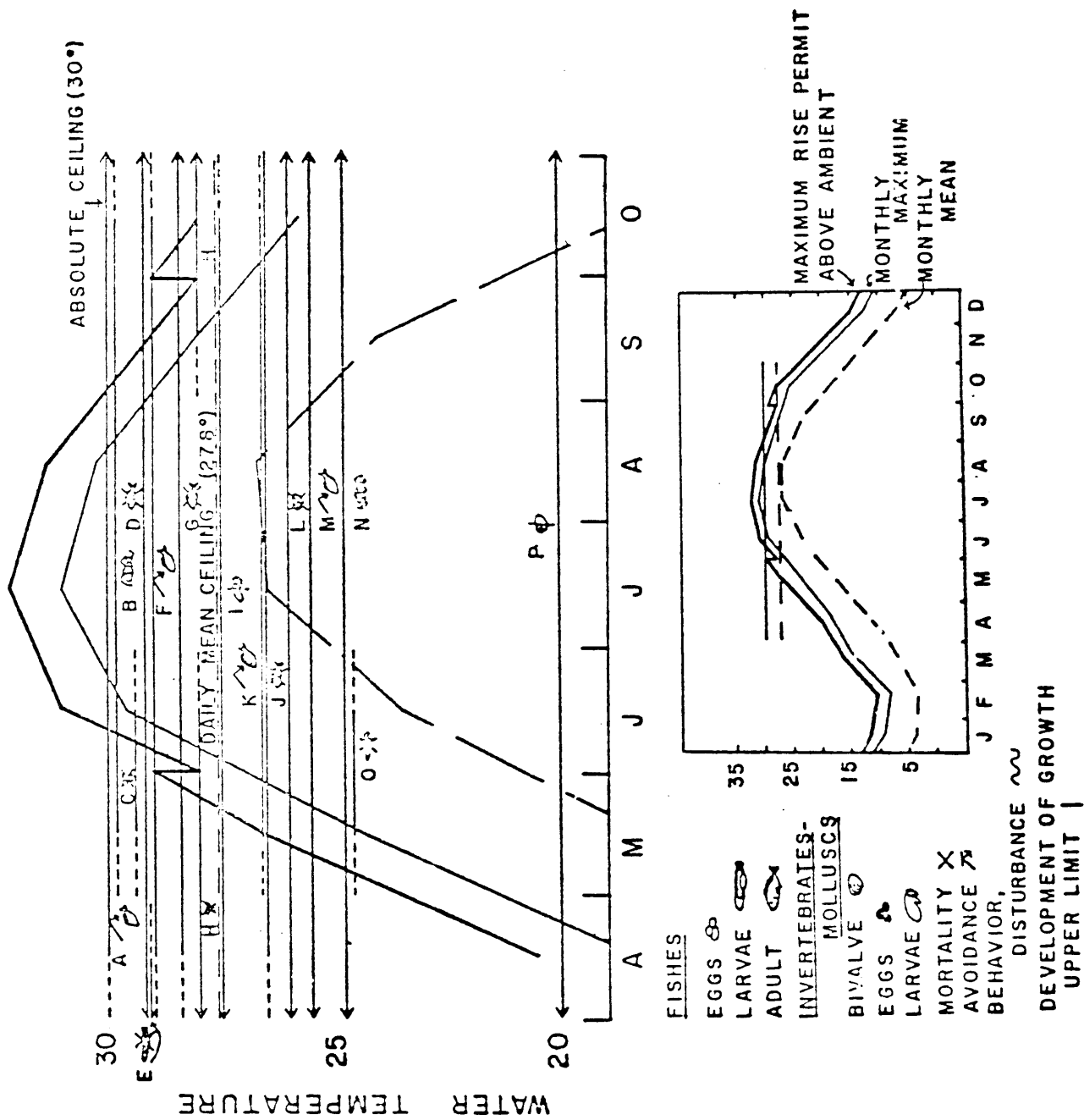


Figure 1. THERMAL EFFECTS ON MARINE SPECIES

TABLE 1. SELECTED THERMAL REQUIREMENTS & LIMITING TEMPERATURE DATA

Atlantic Cold Temperate Biotic Province (Southern Portion):
South of Long Island, N.Y. to Cape Hatteras, N.C.

Figure Designation	Temperature °C	Effect	Species	Seasonal Occurrence	Reference
A	30	Avoidance response breakdown (CTM)	<u>Morone saxatilis</u> (striped bass)	April-November	Gift & Westman, 1971
B	29.8	Behavior-reduced feeding and behavior altered	<u>Pomatomus saltatrix</u> (bluefish)	May-October	Olla, 1971
C	29.4	Survival-eggs (50% optimal survival)	<u>Menidia menidia</u> (Atlantic silverside)	May-June	Everich & Neves (unpublished)
D	29.1	Survival-larvae (TLM)	<u>Mugil cephalus</u> (striped mullet)	January-April (coastal waters)	Cortney & Roberts, 1973
E	29.0	Survival-adult protection limit (TLM - 2.2°C)	<u>Sphaeroides maculatus</u> (Northern puffer)	January-December	Hoff & Westman, 1966
F	29.0	Avoidance response	<u>Brevoortia tyrannus</u> (Atlantic menhaden)	April-October	Meldrim & Gift, 1971
G	29.2	Survival-adult protection limit (TLM - 2.2°C)	<u>Menidia menidia</u> (Atlantic silverside)	April-November	Hoff & Westman, 1966
H	28.0	Survival-adult limit	<u>Mya arenaria</u> (soft shell clam)	January-December	Pfizenmeyer (unpublished)
I	27.5	Development-upper limit larval development	<u>Mulinia lateralis</u> (coot clam)	March-October	Calabrese, 1969
J	26.9	Survival-juvenile protection limit (TLM - 2.2°C)	<u>Pseudopleuronectes americanus</u> (winter flounder)	April-December	Hoff & Westman, 1966
K	26.5	Avoidance response	<u>Cynoscion regalis</u> (sea trout)	May-October	Gift & Westman, 1971
L	26.0	Survival-adult	<u>Mytilus edulis</u> (blue mussel)	January-December	Gonzalez, 1973
M	25.5	Avoidance response	<u>Lefostomus xanthurus</u> (spot)	January-December	Gift & Westman, 1971
N	24.8	Occurrence-maximum temperature for occurrence in Chesapeake Bay	<u>Urophycis regia</u> (spotted hake)	January-December	Barana, 1972
O	24.6	Survival-larvae (TLM)	<u>Menidia menidia</u> (Atlantic silverside)	May-June	Everich & Neves (unpublished)
P	20	Growth-optimum	<u>Mercenaria mercenaria</u> (Northern quahog)	January-December	Ansell, 1968

North of Long Island, a 1.1°C rise above summer ambient provides reasonable protection. For example, maximum short-term temperatures in Narragansett Bay, Rhode Island, usually would not exceed 23.4°C in August (judging from 15-year mean temperature data for Fox Island). Larval Atlantic silversides, juvenile winter flounder, and blue mussel should be protected by that thermal limitation. Thermal protection limit (TLm - 2.2°C) for juvenile winter flounder (Pseudopleuronectes americanus) is 26.9°C (Gift & Westman, 1966). Everich and Neves (unpublished) found that exposure to 24.6°C for 15 days caused 50% mortality of Atlantic silverside larvae (Menidia menidia). Repeated exposures to 25°C would stress the blue mussel (Mytilus edulis), causing cessation of feeding (Gonzalez, 1972) and arrest of embryonic development and larval growth (Hrs-Brenko, unpublished). Diurnal summer maxima exceeding 22°C can alter normal metabolic rates in embryonic tautog (Tautoga onitis) (Laurence, 1973) and cause feeding problems for adult winter flounder (Olla, 1969) and the sand-collar snail (Polinices duplicata) (Hanks, 1953).

Optimum for summer development of the rock crab larva (Cancer irroratus) is 20°C; at 25°C, mortality precludes completion of larval development. Optimum for the northern crab (C. borealis) is 15°C, with development blocked at 20°C (Sastry, unpublished). Between 15 and 20°C, activity of the amphipod (Gammarus oceanicus) is much reduced (Halcrow & Boyd, 1967). Initiation of spawning is often cued by temperature. Blue mussel spawning occurs when spring temperatures reach 12°C (Engle & Loosonoff, 1944). A minimum of 10°C is required for their embryonic development (Hrs-Brenko & Calabrese, 1969) and spawning occurs at 15°C. Migration occurs among striped bass, blue fish and Atlantic silversides (Hennekey, unpublished) at 15°C. Peak spawning runs of American shad (Alosa sapidissima) into rivers occurs at 19.5°C (15 year average, Connecticut River); downstream migration of juveniles occurs as temperature falls below 15.5°C (Leggett & Whitney, 1972). Menhaden migrate at 10°C (Bigelow & Schroeder, 1953); striped bass (Morone saxatilis) migrate into or leave rivers at 6 to 7.5°C (Merrimim, 1941). In the fall and winter, fishes congregate in

discharge plumes which exceed these temperatures. These fishes exhibit increased incidence of disease and a general loss of physiological condition (Mihursky, et al, 1970).

Warm Temperate Zone, Atlantic and Gulf Coasts: This region extends from Cape Hatteras, N.C., to Cape Canaveral, Fla., and on the Gulf Coast from Tampa, Fla., to Mexico. A maximum of 32.2°C is the recommended ceiling. Exposures to temperatures above this level would adversely effect portions of the biota. The upper incipient lethal temperature for two dominant estuarine fishes, mullet and pinfish, is 33°C (Ceck, unpublished). At 33°C, bay anchovy (Anchoa mitchilli) embryonic development is reduced to 50% of optimum (Rebel, 1973). The upper tolerance limit for coot clam embryos (Mulinia lateralis) and for embryos and larvae of American oyster and quahaug is 32.5°C (Anon, 1969). The upper limit for growth of juvenile white shrimp (Panaeus setiferus) is 32.5°C (Zein-Eldin & Griffith, 1969). A decline in field abundance of brown shrimp (P. aztecus) at temperatures above 30°C was reported by Chin (1961).

Protection limits (50% of optimal survival) of two sardines (Harengula jaquana and H. pensacola) for development of the yolk sac larval stage are 31.4°C and 32.2°C, respectively (Rebel, 1973; Sakensa, et al, 1972). The critical thermal maximum (CTM) is exceeded for striped bass at 30°C (Gift & Westman, 1971). Larval pinfish (Lagodon rhomboides), and spot (Leiostomus xanthurus) have CTM's of 31.0°C and 31.1°C, respectively (Hoss, Hettler & Coston, 1973). Protection limit (TLm - 2.2°C) for young-of-the-year Atlantic menhaden is 30.8°C (Lewis & Hettler, 1968). Upper limit for adult growth of the quahaug (Mercenaria mercenaria) is 31°C (Ansell, 1968).

Mean temperatures exceeding 29°C would result in mortality of striped mullet (Mugil cephalus) eggs. Their 96-hr TLm is 26.4°C (Courtenay & Roberts, 1973). Egg and yolk sac larval survival of sea bream (Archosargus rhomboidalis) is reduced to 50% of optimal at 29.1°C. For yellowfin menhaden (Brevoortia smithi), exposure to 29.8°C reduced survival of egg and yolk sac larvae to 50% of optimal (Rebel, 1973). Sublethal but potentially damaging ecological effects could

occur at levels well below 29°C. For example, the upper limit for optimal growth of post larval brown shrimp (Penaeus aztecus) is 27.5°C (Zein-Eldrin & Aldrich, 1965); in the American oyster (Crassostrea virginica) it is 25°C (Collier, 1954). Developing embryos and fry of striped bass cannot tolerate 26.7°C in fresh water (Shannon, 1969). This report may also apply to fry in waters at the head of estuaries. This species spawns in early spring. Elevation of winter temperatures above 20°C in St. Johns River, Florida, could interfere with upstream migration of American shad (Alosa sapidissima) (Leggett & Whitney, 1972).

Tropical Regions: Ceilings for tropical regions such as south Florida (Cape Canaveral and Tampa southward), Puerto Rico, and tropical-zone Pacific Islands are an instantaneous maximum 90°F (32.3°C) and a true daily mean not exceeding 86°F (30°C). A review by Zieman and Wood (in press) suggests that the thermal optimum is 26-28°C (79-82°F) for tropical marine systems, with chronic exposure to temperatures between 28 and 30°C causing heat stress. Death of the biota is readily discernible between 30°C and 32°C (86-89°F). Mayer (1914) recognized that nearshore tropical marine biota normally lives at temperatures only a few degrees below their upper lethal limit. A study of elevated temperature effects on the benthic community in Biscayne Bay, Florida, resulted in the following data (Roessler, 1971):

<u>Phylum</u>	<u>Temperature for High Species Diversity (°C)</u>	<u>Temperature for 50% Species Exclusion (°C)</u>
Molluscs	26.7	31.4
Echinoderms	27.2	31.8
Coelenterates	25.9	29.5
Porifera	24.0	31.2

Other thermal data for tropical biota include a 25.4-27.8°C optimum for fouling community larval settlement (Roessler, 1971); 25°C optimum for larval development of Polydora gibbesi, a commensal crab (Gore, 1968); 27°C for growth and gonad development in sea urchins (Lytechinus variegatus) and for growth in a snail (Cantharus tinctus) (Albertson, 1973); 27 to 28°C optimum for larval development of pink shrimp (Penaeus duorarum) (Thorhaug, et al, 1971); and 30°C optimum for turtle grass (Thalassia testudinum) productivity (Zieman, 1970). Kuthalingham (1959) studied thermal tolerance of newly hatched larvae of ten tropical marine fishes in the laboratory. When held at a series of constant temperatures

for 12 hours, immediately following hatch, optimal survival for all species fell between 28-30°C, but their tolerance limit ranged from 30-32°C.

Thermal stress of the fouling community is seen in 50% reduced settlement rate at 28°C (Roessler, 1971). Fifty percent reduction in gonadal volume of the sea urchin (Lytechinus variegatus) occurs at 29.9°C (Thorhaug, et al, 1971 b). These workers also report irreversible plasmolysis of the macroalga (Valonia ventricosa) at 29.9°C and of V. macrophysa at temperatures above 29.7°C. Survival of developing embryos to the yolk sac larval stage reduced to 50% of optimal at 29.1°C among sea bream (Archosargus rhomboidalis). At 29.8°C, yellowfin menhaden (Brevoortia smithi); and at 31.4°C scaled sardines (Harengula jaguana) suffer similar mortalities during early development (Rebel, 1973). Temperatures in excess of 31-33°C can interfere with embryonic development in six species of mangrove-associated nematodes, even though adults can tolerate 2 to 7°C additional heat (Hopper, et al, 1973). Upper limit for larval (naupliar) metamorphosis in pink shrimp (Penaeus duorarum) is 31.5°C (Thorhaug, et al, 1971 b). Upper lethal temperatures include 31.5°C for five species of Valonia (Thorhaug, 1970); death in 3-8 hours for five Hawaiian corals at 31-32°C (Edmondson, 1928; Jokiel & Coles, 1974); a 32°C TLM (95 hr) for the sea squirt (Ascidia nigra) and sea urchin (Lytechinus variegatus) (Chesher, 1971). Average daily temperatures near 31°C for three to ten days results in decreased growth in seagrass, Thalassia testudinum and red macroalgae, Laurencia poitei. Between 32 and 33°C, health and abundance of these species declines markedly (Thorhaug, 1971, 1973). Replacement of seagrass is slow, especially if rhizomes are damaged due to excessive consumption of stored starch during heat stress (Zieman, 1973). Recovery of Thalassia beds may take decades (Zieman & Wood, in press).

Pacific Coast: Fewer thermal effects studies have been conducted on West Coast species. However, the concept of seasonal restrictions for temperature elevations above ambient are well supported in several East Coast provinces and is deemed applicable to the West Coast as a general biological principle. Data are not sufficient to develop specific regional ceilings. These must be determined on a case-by-

case basis until specific principles emerge.

The Pacific Coast consists of two distinct biogeographical regions. The cold temperate province ranges north from Pt. Conception, California; the warm temperate region from Pt. Conception south. Published data on thermal effects are summarized by biotic province. These should provide a general guideline to prevent possible adverse effects on indigenous species by excessive thermal discharge.

Pacific Cold Temperate Zone: Some winter and spring spawning temperature ranges include 3-6°C for Pacific herring (Clupea pallasii) (McCauley & Hancock, 1971); 7-8°C for English sole (Parophrys vetulus) (Alderdice & Forester, 1968); 13°C for May and June spawning of razor clams (Siliqua patula) (McCauley & Hancock, 1971) and 12-14°C for native little neck clams (Protothaca staminea) (Schink & Woelke, 1973). Optimal growth occurs at 10°C in the small filamentous red algae (Antithamnion spp) (West, 1968), and 12-16°C is optimal for growth and reproduction of various red and brown algae, including kelp (Macrocystis pyrifera) (Druehl & Hisiao, 1969). Twelve to 16°C favors sea grasses, Zostera marina and Phyllospadix scouleri (McRoy, 1970). Spawning migration of striped bass (Morone saxatilis) occurs at 15-18°C (Albrecht, 1964); in American shad (Alosa sapidissima), spawning runs occur at 16.0-19.5°C (Leggett & Whitney, 1972). At Vancouver Island, B.C., distribution of a kelp (Laminaria gzaenlandica) is temperature influenced. (The long stipe form is not found above 13°C; the short stipe form does not occur above 17°C. In the laboratory, elevation of temperature to 13°C produces abnormal sporophytes (Druehl, 1967).) Dungeness crab (Cancer magister) larval development is optimal at 10 and 13.9°C, survival is reduced at 17.8°C, with no survival to megalops at 21.7°C (Reed, 1969). Upper thermal limit for razor clam embryonic and larval development is 17°C (McCauley & Hancock, 1971). Upper growth limit for small filamentous red algae (e.g. Antithamnion spp) is 18°C (West, 1968). King salmon migration into San Juan River may be delayed by estuarine temperatures in excess of 17.8°C (Dunham, 1968).

The sea grass (Phyllospadix scouleri) begins to die off at 20°C (McRoy, 1970), and the pea pod borer (Botula fulcra) ceases to develop

(Fox & Corcoran, 1957). Twenty °C is also the upper limit for embryonic and larval development of the summer-spawning horse clam (Tresus nuttalli) and native little neck clam (Protothaca staminea) (Schink & Woelke, 1973). Upper incipient lethal temperature for the mysid shrimp (Neomysis intermedia) is 21.7°C (Hair, 1971). This value is corroborated by reports of a drop in field populations of this important fish food organism above 22.2°C in the San Joaquin estuary (Heubach, 1969). Twenty-two °C is the upper tolerance limit for embryological development of the wooly sculpin (Clinocottus analis) (Hubbs, 1956). A four hour exposure to 23°C results in significant mortality of the adult razor clam (Siliqua patula) (Woelke, 1971) and the sockeye salmon (Oncorhynchus nerka) (Brett & Alderdice, 1958). Striped bass (Morone saxatilis) are believed stressed at temperatures above 23.9°C (Dunham, 1968). Sexual maturation in a gobiid fish (Gillichthys mirabilis) is blocked at high temperatures. Gonadal regression begins at 22°C in females; at 24°C in males. Gonadal recrudescence will not occur at 24°C or above, regardless of photoperiod (DeVlaming, 1972). The 36 hour TLM for red abalone adults is 23°C when acclimated to 15°C; for the embryos, 26°C, when exposed for 30 hours (Ebert, 1974). Sea urchin (Strongylocentrotus purpuratus) upper tolerance limit is 23.5°C for adults (Gonor, 1968); 25°C is lethal to embryos and renders adults limp and unresponsive after 4 hours (Farmanfarmaian and Giese, 1963).

Pacific Warm Temperate Zone: The thermal threshold for spawning in Pacific sardine (Sardinops caerulea) is 13°C (Marr, 1962). Reports of temperature optima for spawning include 15°C in a ctenophore (Pleurobranchia bachei) (Hirota, 1973); 16°C in the spring spawning wooly sculpin (Clinocottus analis) (Graham, 1970); 17.5°C for northern anchovy (Engraulis mordax); 19°C for opaleye fish (Girella nigricans) (Norris, 1963). Larval survival is best at 16-18°C in white abalone (Haliotis sorenseni) (Leighton, 1972).

Limiting effects of temperature include scarcity of the kelp isopod in the beds above 17.8°C (Jones, 1971). Upper limit for growth in P. bachei is 17°C; 20°C is the upper tolerance limit for the adult

ctenophore (Hirota, 1973). Twenty °C also causes limited survival in recently settled juvenile white abalone (Leighton, 1972). Limiting effects for woolly sculpin include the upper limit of optimal growth at 21°C; at 22°C, a 50% reduction in successful development of eggs; at 24°C, the upper limit for embryonic development is reached (Hubbs, 1966). Sea urchins (Strongylocentrotus sp.) are weakened or killed at 24-25°C (Leighton, 1971). At 25°C, partial osmoregulatory failure occurs in staghorn sculpin (Leptocottus armatus) at 37.6'o/oo (Morris, 1960). A maximum temperature of occurrence of 25°C is reported for top smelt (Atherinops affinis) by Doudoroff (1945) and northern anchovy (Engraulis mordax (Baxter, 1967). For topsmelt, the upper limit at which larvae hatch is 26.8°C (Hubbs, 1965).

Natural summer temperatures are stressful to beds of giant kelp, Macrocystis pyrifera, in southern California. This precludes any thermal discharge in the vicinity of these beds. Deterioration of surface blades is evident from late June onward, due in part to reduced photosynthesis (Clendenning, 1971). Several weeks' exposure to 18.9°C is harmful to the beds (Jones, 1971), while temperatures over 20°C results in pronounced loss of kelp (North, 1964). Brandt (1923) reported some 60% reduction of kelp harvest when the average temperature was 20.65°C and that a bacterial disease, black rot, thrives on kelp at 18-20°C. One day exposure to 22°C is quite harmful to cultured gametophytes of giant kelp (North, 1972).

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CHAPTER III

GUIDANCE MANUAL FOR

INTAKE ENTRAINMENT AND ENTRAPMENT DEMONSTRATIONS

PERFORMED UNDER SEC. 316(b) OF THE FEDERAL WATER

POLLUTION CONTROL AMENDMENTS OF 1972

(P.L. 92-500)

Water Resources Commission
Bureau of Water Management
Michigan Department of Natural Resources

February, 1975

Introduction

Section 316(b) of the Federal Water Pollution Control Act, P.L. 92-500, requires that:

"Any standard established pursuant to section 301 or section 306 of this Act and applicable to a point source shall require that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact."

This guidance manual describes the information which should be developed and evaluated to demonstrate that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts. It is intended for use by owners or operators of point sources who perform demonstrations under section 316(b) and by members of the public who wish to participate in 316(b) demonstrations.

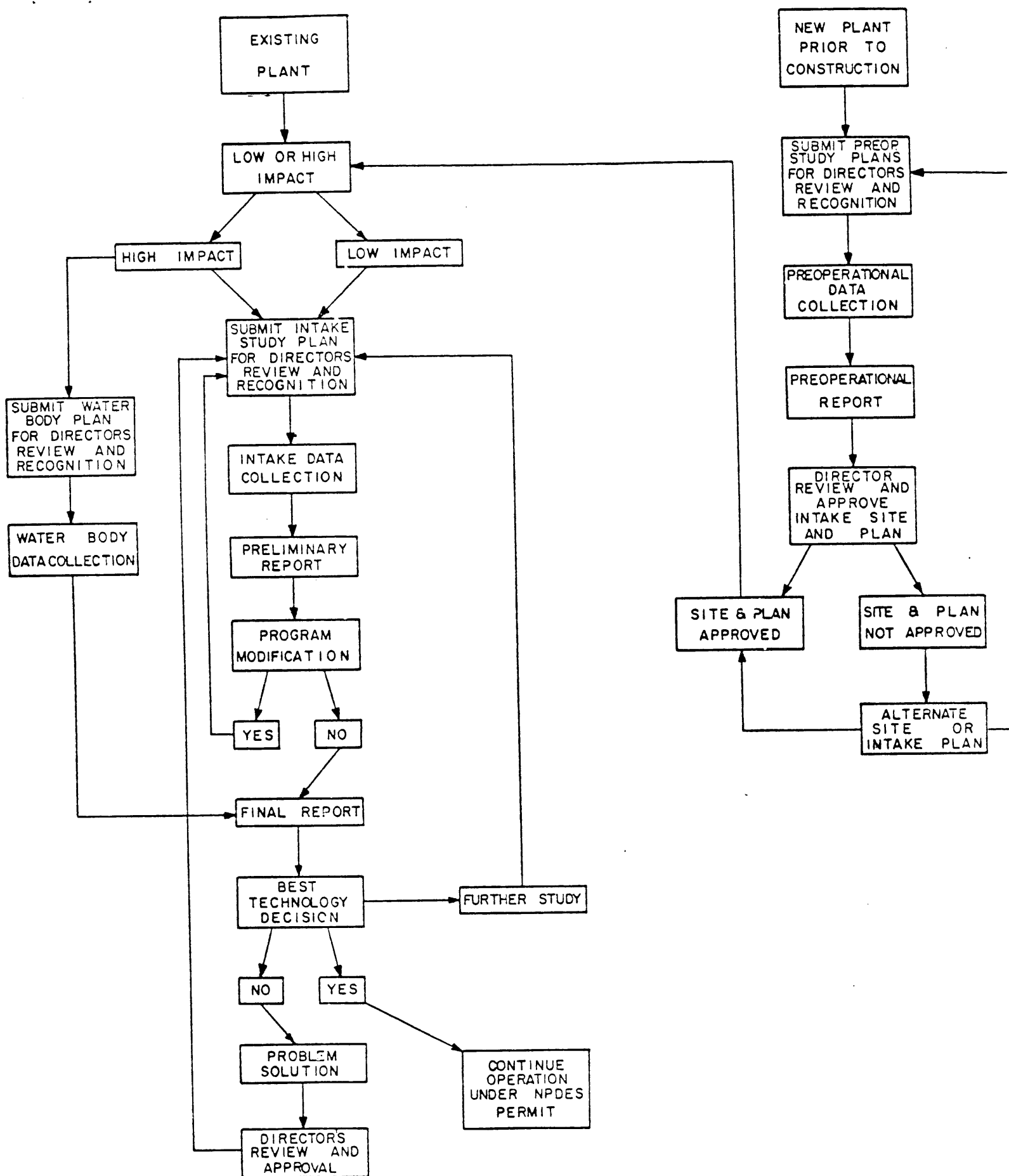
Most of the terms used in this manual are defined in the Michigan Water Resources Commission 316(a) manual, which should be consulted as to the precise meaning of terms such as: balanced indigenous community, Director, discharge zone and water body segment.

The objective of both the 316(b) and 316(a) demonstrations is to evaluate the total impact of each plant's operation on the water resources and balanced indigenous community of aquatic organisms residing in or passing through the vicinity of the plant. In assessing the impact of each plant, the Director will also consider the cumulative effect of all plants on the water body or segment thereof. In most instances, the evaluation of each plant's individual and cumulative impact will be facilitated when the 316(a) and (b) demonstrations are completed and reviewed simultaneously. This will also eliminate duplication of effort since much of the information submitted in the 316(a) demonstration will also apply to the 316(b) demonstration.

To assist the applicant in completing the 316(b) demonstration, a flow chart is included. As seen in this flow chart, the 316(b) process for new plants is more extensive than for existing plants. The objective of this expansion of the 316(b) process for new plants is to predict adverse impacts from new cooling water intake structures prior to their design, siting and construction.

Both the 316(b) and 316(a) processes include a great degree of flexibility and latitude with respect to information required, emphasis in field studies and sampling programs. This flexibility is necessitated by the extreme site-specific variability among Michigan power plants. The flexibility in the design of 316(b) demonstrations, especially for new plants, necessitate that both the Director and the applicant be involved in the planning, conduct and evaluation of field studies and

316 (b) INFORMATION FLOW CHART



demonstrations. Therefore, as seen in the informational flow chart, there are several steps where information and proposals are to be submitted for the Director's review, recognition and/or approval. This will ensure that both the applicant and Director are in agreement as to the scope and specific details of work planned and will provide each party with a set of specific goals and schedules for completion. This submission of information to the Director should also ensure that these studies and demonstrations address the important environmental and plant operational concerns of both parties thereby resulting in a timely and orderly completion of each demonstration. A further benefit from the Director's review, recognition and/or approval of study plans is that studies done throughout a water body segment will utilize methods which result in comparable data. This will assist in evaluating the cumulative effect of all plants within a water body segment as part of the demonstration.

A cooling water intake structure consists of the total structure by which cooling water is transported from the water body through the cooling system and back to the receiving waters. This structure includes circulating and service water pumps, the condenser cooling system and any other in-plant systems or structures used to convey cooling water back to the receiving water.

Adverse environmental impacts that may occur from the operation of cooling water intake structures are due mainly to the damage or destruction of benthic, planktonic and/or nektonic organisms (primarily fishes). The damage or destruction of these organisms within cooling water intake structures and the related cooling

systems is related to various engineering and design parameters and/or biological variables, such as:

- a. Volume of water taken in
- b. The physical configuration and mode of operation of the intake and/or cooling system
- c. Cooling system thermal characteristics
- d. Chemicals added to the cooling system for biological control or water treatment
- e. Number and types of organisms passed through the system
- f. Biological characteristics of organisms taken in

The adverse environmental impacts, since they are influenced by the above variables, need to be determined on a case-by-case basis. Adequate biological data, therefore, are needed at each facility to determine the site-specific needs and control technology necessary to minimize environmental effects and total impact.

Recognizing the extreme site-specific variability possible, an applicant in performing his demonstration under Sec. 316(b) needs to: 1) supply biological information which characterizes the species composition, abundance and the variability (daily and seasonal) in the aquatic organisms damaged or destroyed in his cooling water intake structure; 2) supply biological information which characterizes the species composition, abundance and temporal and spatial variability, the aquatic organisms present in the water body or water segment in the vicinity of his cooling water intake structure; and 3) evaluate available technologies, to identify the "optimal" site-specific best technology available for his cooling water intake structure

location, design, construction, operation and capacity for minimizing adverse environmental effects and total impact.

COOLING WATER INTAKE STRUCTURE MONITORING PROGRAM

To supply the biological information characterizing the species composition, abundance and variability (daily and seasonal) in organisms lost in cooling water intake structures, a cooling water intake structure monitoring program will need to be conducted. This program should be adequate to provide a data base sufficient to document numbers, weights, and length-frequency distribution of each fish species and other aquatic organisms entrapped on the intake screens and trash racks. This program should also estimate the number of fish eggs, larvae and other aquatic organisms entrained and destroyed in the intake water passing through the screening system. Data from this program will be related to information in the water body monitoring program on the abundance and species composition of adult fish, eggs, larvae and other aquatic organisms in the water body in the vicinity of the cooling water intake structure. It is especially important to have information on the temporal and spatial distribution of all organisms in both the water body segment and within the cooling water intake structure to arrive at an accurate estimate of losses.

In addition to determining the numbers of organisms entrapped and entrained, an estimate of the percent of the organisms which are killed must also be obtained during each sampling

period to allow estimation of the total numbers of all organisms killed. Due to the difficulty and costs of obtaining valid estimates of percent mortality, it is suggested that a worst-case approach assuming 100 percent mortality be employed. If no significant impact is detected on this basis then studies of the actual percent mortality will be unnecessary.

As a minimum, the cooling water structure monitoring program should extend throughout one calendar year to obtain an estimate of the yearly losses of all aquatic organisms at each facility. This information will be compared to data from the water body monitoring program to determine the significance of the loss to the populations of organisms in the water body or water body segment.

The sampling regime employed at each facility should be designed to adequately assess throughout the year the impact on various species and life stages of important aquatic organisms residing in or migrating through the area of influence of the cooling water intake structure.

The sampling regime should not only reflect the variability in organisms affected but should also balance data collection with the potential for adverse environmental impacts from the operation of the cooling water intake structure.

Cooling water intake structures at new or proposed plants will be presumed to have a high potential impact unless the applicant can demonstrate otherwise. If the applicant can demonstrate that an existing or proposed cooling water intake structure is of low potential impact the sampling regime and data requirements may be modified by the Director. Low

potential impact cooling water intakes generally are those which meet the following criteria:

- a. The volume of water taken in comprises or would comprise a relatively low percentage of the water body or water body segment or the cross-sectional volume or streamflow.
- b. The structure is or will be located in an area of low biological sensitivity such as offshore areas along Lake Michigan where low numbers of organisms reside or move through.
- c. The structure does not or is not expected to affect the limnological or biological processes outside its immediate vicinity.

The following considerations should be met in the design of the cooling water structure monitoring program:

1. Sampling frequency

- a. General considerations

Since the temporal and spatial distribution of fishes (eggs, larvae, juvenile and adult stages) and other organisms in the source water in the vicinity of any cooling water intake structure is not uniform, a stratified sampling regime should be employed. Such a stratified sampling schedule would include greater sampling frequency during times of the year in which numbers of fish are highly variable and/or fish are spawning in or

migrating through the area. This program could result in a decreased sampling frequency when the number of fish is low and/or variability in numbers is low. Since the volume of cooling water taken in is not uniform over time, a stratified sampling schedule should be employed within a sampling stratum. For example, if during the winter months, the numbers of fish (all life stages) are low and do not vary greatly the sampling frequency might be once every 2 weeks. The sampling date chosen during each 2-week period should reflect the variability in cooling waters withdrawn during all seven days of the week. In other words, sampling would probably be more frequent during the week than on the weekends. However, some samples should be collected on the weekend to accurately assess the total loss of organisms on these days.

- b. Adult and juvenile fish - Sampling should be conducted over a 24-hour period at intervals adequate to assess the species composition and abundance of fish impinged or entrapped on the trash racks and intake screens. The sampling interval should reflect the daily and seasonal numbers of

and variability in fish populations in the vicinity of the cooling water intake structure, both daily and seasonally.

- c. Fish eggs and larvae - Sampling should be conducted over a 24-hour period at intervals adequate to assess species composition and abundance of fish eggs, larvae and other developmental stages entrained in the cooling water and passing through the intake screens. The sampling interval should reflect the daily and seasonal numbers of, and variability in, the immature fish and fish eggs in the vicinity of the cooling water intake structure, both daily and seasonally. Appropriate subsampling techniques may be utilized if numbers of organisms are excessive.
- d. Other aquatic organisms (Phytoplankton, Zooplankton, Macrobenthos) - Same as fish eggs and larvae unless the physical configuration and mode of operation of the cooling water intake structure and/or density and variability (daily and/or seasonal) in populations of important organisms necessitate or permit an alternative sampling frequency.

2. Sampling Methods

- a. Adult and juvenile fish - Accumulated dead fish should be removed from the trash racks prior to sampling. All fish impinged on intake screening

devices can be collected with baskets located at the outlet of the screen washing sluiceway. The mesh size of the collection basket should be smaller than the intake screen mesh. Record the numbers and species of all dead fish impinged on the trash racks and intake screening devices.

- b. Fish eggs and larvae - Preliminary measurements should be performed of the vertical and horizontal distribution of organisms within the cooling water intake structure at the sampling location to ensure that representative samples are obtained. Pumps are the preferred sampling method. Pump rates should be high enough to prevent avoidance by organisms. The pumped water should be filtered through a net of mesh size adequate to collect all organisms present.
- c. Other aquatic organisms (Phytoplankton, Zooplankton, Macrobenthos) - Same as fish eggs and larvae unless the physical configuration and mode of operation of the cooling water intake structure and/or density and variability (daily and/or seasonal) in populations of important organisms necessitate or permit an alternate sampling period.

3. Sampling Data

- a. Adult and juvenile fish - Record species, count, measure (total length) and weigh all fish collected or an adequate sample if numbers are excessive. Indicate subsampling techniques and thereby calculate actual numbers. Select a random sample of each species, eviscerate and determine sex and breeding condition.
- b. Fish eggs and larvae - Determine species, number and size of all larvae collected or an adequate sample if numbers are excessive. Indicate subsampling techniques and thereby calculate actual numbers. Count and, if possible, identify all eggs. Quantify number of eggs and larvae per cubic meter of water taken in.
- c. Other aquatic organisms (Phytoplankton, Zooplankton, Macrobenthos) - Determine number and classify all organisms to lowest practical taxonomic level. Quantify as number per cubic meter of water taken in.

WATER BODY MONITORING PROGRAM

To evaluate the environmental impact of the cooling water intake structure information should be provided on the species composition, density and temporal and spatial variability of

aquatic organisms in the water body or water body segment in the vicinity of the cooling water intake structure. Since in most instances adequate background information with respect to the aquatic organisms present in the water body will not be available, a water body monitoring program will need to be conducted. As in the design of the cooling water intake monitoring program, the design of a water body monitoring program will be site-specific and should balance data acquisition or field work with the potential adverse impact on the populations residing in or moving through the vicinity of the intake.

Existing plants with low potential impact may demonstrate to the Director that field studies in the intake vicinity are not justified especially if adequate background literature is available. New plants and other plants with high potential impact should provide information on the aquatic community in the water body segment. This information may be obtained through field studies and/or literature pertaining to the plant vicinity or water body segment. The specific design of water body field studies should:

1. Emphasize the important organisms present or potentially impacted by the intake.
2. Complement the intake monitoring program with respect to sampling frequency and methods so that data may be correlated between the two programs.
3. Employ methods and gear that are appropriate to the organisms present, life stages expected and daily and/or seasonal changes or variability

in the abundance and species composition of
-- these organisms.

4. Provide information which can be correlated with similar programs at other cooling water intake structures in the water body segment. This will assist in evaluating the cumulative effects of these intake structures.

As in the cooling water intake structure monitoring program, the water body monitoring program should be designed, implemented and modified with the Director's review, recognition or approval. The same degree of flexibility will be utilized in the design, review and modification of both monitoring programs.

PLANT OPERATIONAL AND ENGINEERING INFORMATION

For those plants performing 316(a) demonstrations, most of the engineering information pertinent to a 316(b) study should be provided in the sections on Plant Operational Data and Hydrology. Requirements for these sections are outlined in the Michigan Water Resources Commission's 316(a) Guidance Manual. For both existing and proposed plants pertinent information should be provided which will adequately describe the physical configuration and mode of operation of the cooling water intake system. In addition, pertinent in-plant operating or engineering information, which directly or indirectly applies or affects the operation of the cooling water intake system, should be supplied. The following are examples of specific data to be recorded during the intake monitoring period and for which all pertinent information on daily, seasonal and annual variability

should be included:

- (1) Volume pumped and number and rated capacity of circulating water pumps in operation, plus a description of pumps.
- (2) Temperature - intake, discharge and rate of increase across condensers.
- (3) Time started, duration and amount of warm water recirculation for intake tempering, deicing and any short circuiting.
- (4) Chlorine, other biocides and/or chemicals added to the condenser cooling water and a determination of the chemical forms and concentrations throughout the cooling system.
- (5) Current velocity at intake(s) over range of water volumes used in plant operation and for receiving water flows or levels. Velocity profile across screen should be provided.
- (6) Number of times screens are operated between sampling intervals and throughout the year.
- (7) The distance from shore and depth from which water is withdrawn.
- (8) Time of passage through the various major portions of the cooling system from the intake structure to the point of discharge.
- (9) Specifications on trash rack, screen mesh, cleaning devices (physical and chemical), live organism return and diversion devices.

- (10) Capability of variable depth withdrawal and
-- operational changes with seasons.

CONTENTS AND FORMAT OF PRESENTATION

The 316(b) demonstration should present all data and related information collected in the cooling water intake structure and water body monitoring programs and/or related literature. In addition, the applicant should present all pertinent plant operational and engineering information obtained during the cooling water structure and water body monitoring programs on the location, design, construction, capacity and operation of the cooling water intake structure and in-plant systems utilizing cooling water furnished by this structure. The applicant should then, based on these data and information, demonstrate, as required by Sec. 316(b) of the Act, that at this plant:

"... the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact."

The data from the intake and water body monitoring programs should be presented using tables, graphs, statistical tests, population models and/or any other means useful in describing the species composition, abundance and temporal or spatial variability in the organisms present in the vicinity of the intake and the impact of the intake on these organisms.

These data should also be incorporated into a projection, on a species basis, of the annual losses at this intake of fish

eggs, larvae and adults and other aquatic organisms using the worst-case approach; i.e. assume 100 percent mortality of all organisms entrained and/or entrapped. The demonstration should include a rationale explaining why this loss of these organisms is not adversely affecting the aquatic community in the vicinity of the intake and that the cumulative effect of this intake with others in the water body segment is not adversely affecting the aquatic communities present throughout the water body segment.

The demonstration should also, based on data collected and literature available, estimate the impact of the cooling water intake on aquatic organisms expected in the immediate vicinity and throughout the water body segment under theoretical conditions which would exist when point source discharges of pollutants are in compliance with section 301(b) of the Act (P.L. 92-500). Species expected should be based on historical data and/or information on the biota of appropriate nearby relatively unpolluted waters such as upstream unaffected areas.

Specific information which should be presented to assist in evaluating the impact of this structure include:

1. A map showing the temporal and spatial distribution of organisms in biologically important areas in the vicinity of the intake structures. These are areas such as spawning grounds, nursery areas, migratory routes, high populations of macrobenthic organisms, and any lake or river areas where important organisms might

be excessively removed or destroyed.

2. Estimates of the redistribution of organisms (all life stages) from these areas to another and a description of the resultant habitat changes.
3. Data on water body dissolved oxygen and temperatures expected throughout the year.
4. Information on fish (all life stages) swimming speeds for representative important species for the temperatures expected throughout the year in the vicinity of the intake.

The specific format of the demonstration should include:

1. Pagination.
2. A detailed table of contents.
3. Supportive reports, documents and raw data which are not from the open scientific literature.
4. Bibliographic citations to page number.
5. An interpretive, comprehensive narrative summary of the demonstration which will serve, in part, as the basis for the Director's decision. The summary should include a table of contents and may include tables and figures. Sources of data used in the summary should be cited to page number. The summary should include a clear discussion stating why the demonstration shows that the location, design, construction, capacity and

operation of the cooling water intake structure minimize impact on the water resources and aquatic community in the vicinity of the intake and throughout the water body segment.

CHAPTER IV

"REPRESENTATIVE IMPORTANT SPECIES"

For

Use in 316 Demonstrations for Michigan's
Electric Generating Facilities

by

MICHIGAN WATER RESOURCES COMMISSION
MICHIGAN DEPARTMENT OF NATURAL RESOURCES

July 25, 1974

Water Quality Control
and Fisheries Divisions
Cooperating

Figure 1. Geographical zones used in selection of Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500.

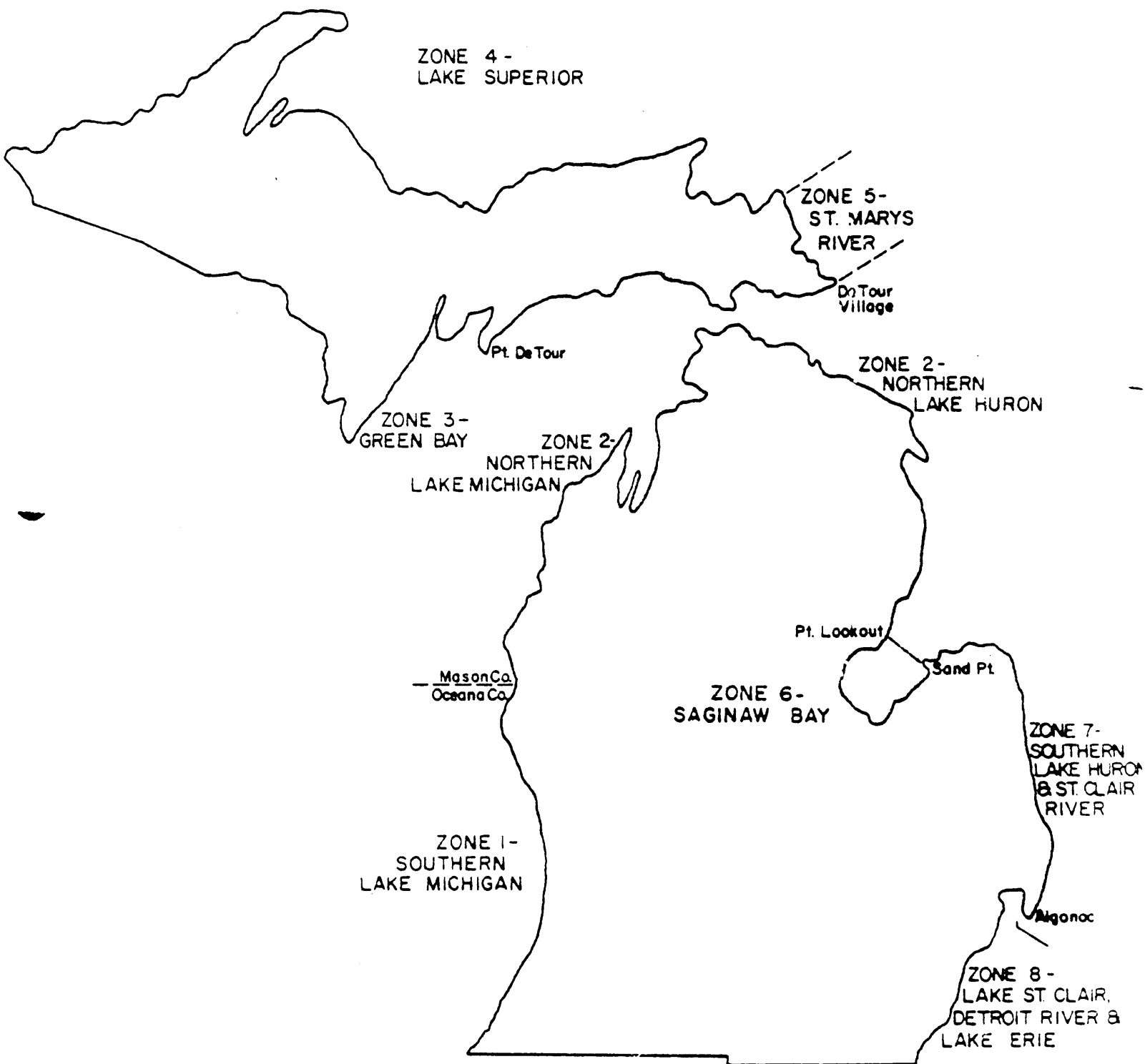


Table 1. Zones used in selection of Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500.

- ZONE 1 -- Michigan waters of Lake Michigan south of a westerly extension of the Mason/Oceana county line and north of the Indiana-Michigan boundary.
- ZONE 2 -- Michigan waters of northern Lake Michigan north of a westerly extension of the Mason/Oceana county line, exclusive of Green Bay west of Point Detour, Delta County, and Michigan waters of northern Lake Huron north of Point Lookout, Arenac County, exclusive of the St. Marys River and connecting waters north of DeTour Village, Mackinac County.
- ZONE 3 -- Michigan waters of Green Bay west of Point Detour, Delta County.
- ZONE 4 -- Michigan waters of Lake Superior.
- ZONE 5 -- Michigan waters of the St. Marys River, Potagannissing Bay and Munuscong Lake north of DeTour Village, Mackinac County.
- ZONE 6 -- Saginaw Bay southwesterly of a line from Point Lookout, Arenac County, to Sand Point, Huron County.
- ZONE 7 -- Michigan waters of Lake Huron from Sand Point, Huron County, southerly to Port Huron, and the St. Clair River inclusive of the north and middle channels at Algonac.
- ZONE 8 -- Michigan waters of Lake St. Clair, the Detroit River and Lake Erie.
- ZONE 9 -- Inland warmwater locations and anadromous migratory routes.

Table 2. Michigan biota to be considered in demonstration to satisfy
Section 31G, P.L. 92-500, Zone 1, southern Lake Michigan,
page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
Filamentous algae	N, CI	*
Macrophyton	N, CI	*
Phytoplankton	F, CI	*
Zooplankton	F, CI	*
Macroinvertebrates	F, CI	*
Fish		
Acipenseridae		**
Lake sturgeon	T	
Catostomidae		(3)
White sucker	F, C, S	all
Longnose sucker	F, C	
Clupeidae		all
Alewife	F	
Coregonidae		**
Lake herring	T, C	**
Shortnose cisco	T	**
Shortjaw cisco	T	**
Kiyi cisco	T	all
Lake whitefish	CI, C	**
Bloater	T, C	
Cottidae		(4)
Slimy sculpin	F	(4)
Mottled sculpin	F	
Cyprinidae		all
Carp	PT	all
Spottail shiner	F	**
Emerald shiner	T, F	(4)
Longnosed dace	F	
Gadidae		**
Burbot	CI	
Gasterosteidae		(4)
Ninespine stickleback	F	
Osmeridae		spawning, larvae (5)
Rainbow smelt	S, F	
Percidae		spawning, larvae (5)
Yellow perch	S, C, F	**
Logperch	T, F	
Percopsidae		(4)
Troutperch	F	
Salmonidae		adults (6)
Lake trout	S	all
Rainbow trout	S	adults
Brown trout	S	all
Coho salmon	S	(7)
Chinook salmon	S	**
Atlantic salmon	NC	

* Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.

(1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered.

(2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.

(3) Other activities represented by longnose sucker.
 (4) " " " " " spottail shiner.
 (5) " " " " " alewife.
 (6) " " " " " whitefish.
 (7) " " " " " coho salmon.
 (3) " " " " " rainbow trout.

Table 3. Michigan data to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 2, northern Lakes Michigan and Huron, page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
<u>Filamentous algae</u>	N, CI	*
<u>Macrophyton</u>	N, CI	*
<u>Phytoplankton</u>	F, CI	*
<u>Zooplankton</u>	F, CI	*
<u>Macroinvertebrates</u>	F, CI	*
<u>Fish</u>		
<u>Acipenseridae</u>		**
Lake sturgeon	T	
<u>Catostomidae</u>		(3)
Longnose sucker	F, C, S	
White sucker	F, C, S	all
<u>Clupeidae</u>		all
Alewife	F	
<u>Centrarchidae</u>		all
Smallmouth bass	S	
<u>Coregonidae</u>		**
Lake herring	T	**
Shortnose cisco	T	**
Shortjaw cisco	T	**
Longjaw cisco	T	**
Kiyi cisco	T	**
Lake whitefish	CI, F, C	all (7)
Bloater	T	**
Round whitefish	CI, F, C	(4)
<u>Cottidae</u>		(5)
Mottled sculpin	F	(5)
Slimy sculpin	F	
<u>Cyprinidae</u>		all
Carp	PT	all
Spottail shiner	F	** (5) (7)
Emerald shiner	F	
<u>Esocidae</u>		all
Northern pike	S	
<u>Gadidae</u>		** (8)
Burbot	CI	
<u>Gasterosteidae</u>		(5)
Threespine stickleback	F	
<u>Osmeridae</u>		spawning, larvae (6)
Rainbow smelt	F, S	
<u>Percidae</u>		spawning, larvae (6)
Yellow perch	F, S	(5)
Walleye	S, CI	(9)
Logperch	F	** (8) (9)
Sauger	S	
<u>Percopsidae</u>		(5)
Trout perch	F	
<u>Salmonidae</u>		adult= (4)
Lake trout	S	(10) (12)
Brook trout	S	(10)
Splake	S	all
Rainbow trout	S	(10) (12)
Brown trout	S	migration (10)
Coho	S	(10) (11)
Chinook	S	(10) (11)
Atlantic salmon	S	(10) (11)

* Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.

(1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered.

(2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.

(3) Other activities represented by white sucker.

(4) " " " " whitefish.

(5) " " " " spottail shiner.

(6) " " " " alewife.

(7) Threatened in Lake Michigan. All life forms or activities to be evaluated in Lake Michigan.

(8) Threatened in Lake Huron. All life forms or activities to be evaluated in Lake Huron.

(9) Other activities represented by yellow perch.

(10) " " " " lake trout.

(11) " " " " coho salmon.

(12) " " " " rainbow trout.

Table 4. Michigan biota to be considered in demonstration to satisfy Section 316,
P. L. 92-500, Zone 3, Green Bay, page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
Filamentous algae	N, CI	*
Macrophyton	N, CI	*
Phytoplankton	F, CI	*
Zooplankton	F, CI	*
Macroinvertebrates	F, CI	*
Fish		
Acipenseridae		
Lake sturgeon	T	**
Catostomidae		
White sucker	F	(3)
Longnose sucker	F	all
Centrarchidae		
Smallmouth bass	S	all
Clupeidae		
Alewife	F	all
Coregonidae		
Lake herring	T	**
Shortnose cisco	T	**
Shortjaw cisco	T	**
Kiyi cisco	T	**
Lake whitefish	CI, C	all
Bloater	T, C	**
Round whitefish	CI, C	(4)
Cottidae		
Slimy sculpin	F	(5)
Mottled sculpin	F	(5)
Cyprinidae		
Carp	PT	all
Spottail shiner	F	all
Emerald shiner	T, F	**
Esocidae		
Northern pike	CI, S	all
Gadidae		
Burbot	CI	**
Gasterosteidae		
Minespine stickleback	F	(5)
Lepidosteidae		
Longnose gar	NC	**
Osmeridae		
Rainbow smelt	F, S	spawning, larvae (6)
Percidae		
Yellow perch	F, S	spawning, larvae (6)
Walleye	S, CI	(6) (7)
Sauger	S, CI	(6) (7)
Logperch	F	all
Percopsidae		
Trout perch	F	(5)
Salmonidae		
Lake trout	S	adults (4)
Rainbow trout	S	all
Brown trout	S	(4) (9)
Coho	S	migration (4)
Chinook	S	(4) (8)
Atlantic salmon	S	(4) (9)

* Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.

(1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered; NC, not common.

(2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.

(3) Other activities represented by sucker.
 (4) " " " " whitefish
 (5) " " " " spottail shiner
 (6) " " " " alewife.
 (7) " " " " yellow perch
 (8) " " " " lake trout
 (9) " " " " rainbow trout

Table 5. Michigan biota to be considered in demonstration to satisfy Section 316,
P. L. 92-500, Zone 4, Lake Superior, page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
Filamentous algae	N, CI	*
Macrophyton	N, CI	*
Phytoplankton	F, CI	*
Zooplankton	F, CI	*
Macroinvertebrates	F, CI	*
<u>Fish</u>		
<u>Acipenseridae</u>		
Lake sturgeon	T	**
<u>Catostomidae</u>		
White sucker	F, C, S	(3)
Longnose sucker	F, C, S	all
<u>Coregonidae</u>		
Lake herring	T	**
Shortnose cisco	T	**
Shortjaw cisco	T	**
Blackfin cisco	T	**
Kiyi cisco	T	**
Lake whitefish	CI, C	all
Bloater	T, C	**
Round whitefish	CI, C	(4)
<u>Cottidae</u>		
Slimy sculpin	F	all
Mottled sculpin	F	(5)
Spoonhead sculpin	T	**
<u>Cyprinidae</u>		
Spottail shiner	F	all
Emerald shiner	F	(6)
<u>Gadidae</u>		
Burbot	CI	**
<u>Gasterosteidae</u>		
Ninespine stickleback	F	all
<u>Osmeridae</u>		
Rainbow smelt	S, F	all
<u>Percidae</u>		
Yellow perch	S, F	all
Walleye	S, CI	(7)
Sauger	S	(7)
Johnny darter	F	(6) (7)
<u>Salmonidae</u>		
Lake trout	S	all
Brook trout	S	(8) (10)
Rainbow trout	S	all
Brown trout	S	(8) (10)
Coho salmon	S	all
Chinook salmon	S	(8) (9)
Atlantic salmon	S	(8) (9)

* Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.

(1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered.

(2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.

(3) Other activities represented by longnose sucker.
 (4) " " " " lake whitefish.
 (5) " " " " slimy sculpin.
 (6) " " " " spottail shiner.
 (7) " " " " yellow perch.
 (8) " " " " lake trout.
 (9) " " " " coho salmon.
 (10) " " " " rainbow trout.

Table 6. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 5, St. Marys River, etc., page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
<u>Filamentous algae</u>	N, CI	*
<u>Macrophyton</u>	F, N, CI	*
<u>Phytoplankton</u>	F, CI	*
<u>Zooplankton</u>	F, CI	*
<u>Macroinvertebrates</u>	F, CI	*
<u>Fish</u>		
<u>Acipenseridae</u>		
Lake sturgeon	T	**
<u>Catostomidae</u>		
White sucker	F, S	(3)
Longnose sucker	F, S	all
<u>Clupeidae</u>		
Alewife	F	all
<u>Coregonidae</u>		
Lake whitefish	CI, F, S	all
Round whitefish	F	(4)
Lake herring	T, F	**
Bloater	T, F	**
Shortjaw cisco	T	**
Shortnose cisco	T	**
Kiyi cisco	T	**
<u>Centrarchidae</u>		
Rock bass	S, CI	all
Smallmouth bass	S, CI	(5)
<u>Cottidae</u>		
Slimy sculpin	F	(6)
Mottled sculpin	F	all
<u>Cyprinidae</u>		
Carp	PT, F, S	all
Spottail shiner	F	(7)
Emerald shiner	F	all
Longnose dace	F	(7)
<u>Esocidae</u>		
Northern pike	CI, S	(8) (9)
Muskellunge	T, CI, S	**
<u>Gadidae</u>		
Burbot	CI	**
<u>Osmeridae</u>		
Rainbow smelt	F, S	spawning, larvae (9)
<u>Percidae</u>		
Yellow perch	F, S	spawning, larvae (9)
Walleye	S	(8) (9)
Sauger	T, S	**
Johnny darter	F	(10)
Logperch	F	all
<u>Salmonidae</u>		
Lake trout	S	adults (4)
Brook trout	S	(11)
Splake	S	(4) (11)
Rainbow trout	S	all
Brown trout	S	(4) (11)
Coho salmon	S	migration (4) (11)
Chinook salmon	S	(12)
Pink salmon	S, NC	**
Atlantic salmon	NC	**

* Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.

(1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered; NC, not common.

(2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.

(3) Other activities represented by longnose sucker.

- (4) " " " " whitefish
- (5) " " " " rock bass
- (6) " " " " mottled sculpin
- (7) " " " " emerald shiner
- (8) " " " " yellow perch
- (9) " " " " alewife
- (10) " " " " logperch
- (11) " " " " rainbow trout
- (12) " " " " coho salmon

Table 7. Michigan biota to be considered in demonstration to satisfy Section 316,
P.L. 92-500, Zone 6, Saginaw Bay, page 1 of 2 pages.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
<u>Filamentous algae</u>	N, CI	*
<u>Macrophyton</u>	F, N, CI	*
<u>Phytoplankton</u>	F, CI	*
<u>Zooplankton</u>	F, CI	*
<u>Macroinvertebrates</u>	F, CI	*
<u>Fish</u>		
<u>Acipenseridae</u>		
Lake sturgeon	T	**
<u>Amiidae</u>		
Bowfin	CI	(3)
<u>Catostomidae</u>		
White sucker	F, S	all
Bigmouth buffalo	F	(4)
Northern redbhorse	F, S	(4)
<u>Centrarchidae</u>		
Smallmouth bass	S	all
Largemouth bass	S	all
Rock bass	S	(13)
Black crappie	S	(3)
Bluegill	S	(3)
Pumpkinseed	S	(3)
<u>Clupeidae</u>		
Alewife	F	all
Gizzard shad	F	(5)
<u>Coregonidae</u>		
Lake whitefish	F, C	all
Shortnose cisco	T	**
Shortjaw cisco	T	**
Kiyi cisco	T	**
Bloater	T	**
Lake herring	T	**
<u>Cottidae</u>		
Slimy sculpin	F	(6)
<u>Cyprinidae</u>		
Carp	PT, F, C, S,	all
Goldfish	PT, F	all
Golden shiner	F	(6)
Spottail shiner	F	all
<u>Esocidae</u>		
Northern pike	S	all
<u>Gadidae</u>		
Burbot	T	**
<u>Ictaluridae</u>		
Channel catfish	S, F, C	all
Brown bullhead	F, S	(7)
Black bullhead	F, S	(7)
Stonerat	CI	(7)
<u>Lepisosteidae</u>		
Longnose gar	CI	all
<u>Osmeridae</u>		
Rainbow smelt	F, S	spawning, larvae (5)
<u>Percichthyidae</u>		
White bass	S, F	(8)
<u>Percidae</u>		
Yellow perch	F, S	all
Walleye	S	(8)
Sauger	S	(8)
Logperch	F	all
<u>Salmonidae</u>		
Lake trout	S	adults (9)
Rainbow trout	S	all
Brown trout	S	(10) (12)
Coho salmon	S	migration (10) (12)
Chinook salmon	S	(10) (11) (12)
<u>Sciaenidae</u>		
Freshwater drum	S, F, C	eggs (7)

Table 7. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 6, Saginaw Bay, page 2 of 2 pages.

- * Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.
- ** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.
- (1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered.
- (2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.
- (3) Other activities represented by largemouth bass.
- (4) " " " " white sucker.
- (5) " " " " alewife.
- (6) " " " " spottail shiner.
- (7) " " " " channel catfish.
- (8) " " " " yellow perch.
- (9) " " " " whitefish.
- (10) " " " " rainbow trout.
- (11) " " " " coho salmon.
- (12) " " " " lake trout.
- (13) " " " " smallmouth bass.

Table 8. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 7, southern Lake Huron and St. Clair River, page 1 of 2 pages.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
<u>Filamentous algae</u>	N, CI	*
<u>Macrophyton</u>	N, CI	*
<u>Phytoplankton</u>	F, CI	*
<u>Zooplankton</u>	F, CI	*
<u>Macroinvertebrates</u>	F, CI	
<u>Fish</u>		
<u>Acipenseridae</u>		
Lake sturgeon	T	**
<u>Amiidae</u>		
Bowfin	CI, MC	**
<u>Atherinidae</u>		
Brook silversides	F	(3)
<u>Catostomidae</u>		
White sucker	F, S	all
Longnose sucker	F	(4)
Quillback	F	eggs, larvae, fry
Northern redbhorse	F, S	(5)
Hog sucker	F	(4)
<u>Centrarchidae</u>		
Smallmouth bass	S	all
Rock bass	S	(6)
<u>Clupeidae</u>		
Alosa	F	all
Gizzard shad	F	(7)
<u>Coregonidae</u>		
Lake whitefish	CI, F, C	all
Lake herring	T	**
Shortnose cisco	T	**
Shortjaw cisco	T	**
Kiyi cisco	T	**
Bloater	T	**
Round whitefish	T	**
<u>Cottidae</u>		
Slimy sculpin	F	(3)
Mottled sculpin	F	(3)
<u>Cyprinidae</u>		
Carp	PT, F, C, S	all
Spottail shiner	F	(3)
Emerald shiner	F	(3)
Bluntnose minnow	F	all
Goldfish	PT, F	all
Silver chub	T	**
<u>Esocidae</u>		
Northern pike	S	all
Muskellunge	S	(8)
<u>Gadidae</u>		
Burbot	CI	all
<u>Gasterosteidae</u>		
Ninespine stickleback	F	all
Brook stickleback	F	(9)
<u>Hiodontidae</u>		
Mooneye	NC	**
<u>Ictaluridae</u>		
Channel catfish	S, F	all
Black bullhead	S, F	(10)
Brown bullhead	S, F	(10)
Stoneroller	CI, F	(10)
<u>Lepisosteidae</u>		
Longnose gar	CI	all
<u>Osmeridae</u>		
Rainbow smelt	F, S	spawning, larvae, (7)
<u>Percid</u>		
Yellow perch	F, S	spawning, larvae, (7)
Walleye	F, S	(7) (11)
Sauger	F, S	(7) (11)
Logperch	F	all
Johnny darters	F	(12)
<u>Perrichthyidae</u>		
White bass	S, F	all
<u>Percopsidae</u>		
Trout perch	F	(3)
<u>Salmonidae</u>		
Lake trout	S	adults (13)
Splake	S	(13) (14)
Rainbow trout	S	all
Brown trout	S	(13) (15)
Coho salmon	S	migration (13)
Chinook salmon	S	(15) (16)
Atlantic salmon	S	(15) (16)
<u>Sciaenidae</u>		
Freshwater drum	S, F	eggs (10)

Table 8. Michigan biota to be considered in demonstration to satisfy Section 316.
P.L. 92-500, Zone 7, southern Lake Huron and St. Clair River, page 2 of
2 pages.

- * Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.
 - ** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.
- (1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered; NC, not common.
 - (2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.
 - (3) Other activities represented by bluntnose minnow.
- | | | | | | |
|------|---|---|---|---|------------------------|
| (4) | " | " | " | " | white sucker. |
| (5) | " | " | " | " | quillback. |
| (6) | " | " | " | " | smallmouth bass. |
| (7) | " | " | " | " | alewife. |
| (8) | " | " | " | " | northern pike. |
| (9) | " | " | " | " | ninespine stickleback. |
| (10) | " | " | " | " | channel catfish. |
| (11) | " | " | " | " | yellow perch. |
| (12) | " | " | " | " | logperch. |
| (13) | " | " | " | " | whitefish. |
| (14) | " | " | " | " | lake trout. |
| (15) | " | " | " | " | rainbow trout. |
| (16) | " | " | " | " | coho salmon. |

Table 9. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 8, Lake Erie, Lake St. Clair and Detroit River, page 1 of 2 pages.

Important species or category	"Representative important species" Rationale for thermal component of discharge	
	(1) Life form or activity to be evaluated	(2)
Filamentous algae	N, CI	*
Macrophyton	F, N, CI	*
Phytoplankton	F, CI	*
Zooplankton	F, CI	*
Macroinvertebrates	F, CI	*
Fish:		
<u>Acipenseridae</u>		
Lake sturgeon	T	**
<u>Amiidae</u>		
Bowfin	CI, NC	**
<u>Atherinidae</u>		
Brook silversides	F, NC	**
<u>Catostomidae</u>		
White sucker	F, C, S	all
Quillback	F, C	(3)
Northern redhorse	F, C, S	(3)
Hog sucker	F	(3)
Spotted sucker	F	(3)
Black buffalo	T, F	(3)
Bigmouth buffalo	F, C	(3)
<u>Centrarchidae</u>		
Largemouth bass	S	all
Smallmouth bass	S	all
Rock bass	S	(4)
Bluegill	S, NC	**
Pumpkinseed	S	(5)
Black crappie	S, NC	**
White crappie	S	(5)
<u>Clupeidae</u>		
Gizzard shad	F	all
Alewife	F	(6)
<u>Coregonidae</u>		
Lake whitefish	T	**
Lake herring	T	**
<u>Cottidae</u>		
Slimy sculpin	F	all
Mottled sculpin	F	(7)
<u>Cyprinidae</u>		
Carp	PT, F, C	all
Goldfish	PT, F	all
Golden shiner	F	(8)
Spottail shiner	F	(8)
Emerald shiner	F	all
Silver chub	T	**
<u>Esocidae</u>		
Northern pike	S	all
Muskellunge	T, S	(11)
<u>Gadidae</u>		
Burbot	T	**
<u>Hiodontidae</u>		
Mooneye	NC	eggs, larvae, fry (6)
<u>Ictaluridae</u>		
Channel catfish	S	all
Black bullhead	S	(9)
Brown bullhead	S	(9)
Stonecat	NC	**
<u>Lepisosteidae</u>		
Longnose gar	CI	all
<u>Osmeridae</u>		
Rainbow smelt	F, S	all
<u>Percidae</u>		
Yellow perch	S	all
Walleye	S	(10)
Sauger	T	all
Logperch	F	(8)
Johnny darter	F	(8)
<u>Percichthyidae</u>		
White bass	S	all
White perch	S	(10)
<u>Percnopsidae</u>		
Trout perch	F	(8)
<u>Salmonidae</u>		
Rainbow trout	S	all
Coho salmon	S	all
Chinook salmon	S	all
<u>Sciaenidae</u>		
Freshwater drum	S, F	eggs (9)

Table 9. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 8, Lake Erie, Lakes St. Clair and Detroit River, page 2 of 2 pages.

- * Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.
- ** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.
- (1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered.
- (2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism add other activities which are or may be necessary to maintain population integrity.
- (3) Other activities represented by white sucker.
- (4) " " " " smallmouth bass.
- (5) " " " " largemouth bass.
- (6) " " " " gizzard shad.
- (7) " " " " slimy sculpin.
- (8) " " " " emerald shiner.
- (9) " " " " channel catfish.
- (10) " " " " yellow perch
- (11) Threatened in Lake Erie. All life forms or activities to be evaluated in Lake Erie.

Table 10. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 9, inland warmwater locations and anadromous migratory routes, drowned river mouths, Lake Michigan, page 1 of 2 pages.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
Filamentous algae	N, CI	*
Macrophytton	F, N, CI	*
Phytoplankton	F, CI	*
Zooplankton	F, CI	*
Macroinvertebrates	F, CI	*
Fish		
Acipenseridae		
Lake sturgeon	T, S	**
Amiidae		
Bowfin	CI	(3)
Atherinidae		
Brook silversides	F	all
Catostomidae		
White sucker	F, S	all
Longnose sucker	F, S	(4)
Lake chubsucker	F	(4)
Hog sucker	F	(4)
Quillback	F, CI	(4)
Northern redhorse	F, S	(4)
Spotted sucker	F	(4)
Centrarchidae		
Smallmouth bass	S	all
Largemouth bass	S	all
Rock bass	S	(5)
Bluegill	S	(3)
Pumpkinseed	S	(3)
Green sunfish	S	(3)
Black crappie	S	(3)
Clupeidae		
Alewife	F	all
Gizzard shad	F	(6)
Cottidae		
Slimy sculpin	F	(7)
Mottled sculpin	F	all
Cyprinidae		
Carp	PT, F, S	all
Goldfish	PT, F, S	all
Golden shiner	F	(8)
Common shiner	F	(8)
Creek chub	F	(8)
Bluntnose minnow	F	(8)
Spotfin shiner	F	(8)
Spottail shiner	F	(8)
Emerald shiner	T, F	**
Blacknose shiner	F	(8)
Cyprinodontidae		
Banded killifish	F, NC	**
Esocidae		
Northern pike	S	all
Mud pickerel	CI	(9)
Gobiidae		
Burbot	S	all
Ictaluridae		
Channel catfish	S	all
Flathead catfish	S, NC	**
Black bullhead	S	(10)
Brown bullhead	S	(10)
Yellow bullhead	S	(10)
Stonecat	CI	(10)
Tadpole madtom	CI, NC	**
Lepisosteidae		
Longnose gar	CI	all
Spotted gar	CI	(4)
Osmeridae		
Rainbow smelt	F	all
Percidae		
Walleye	S	(12)
Yellow perch	S, F	all
Logperch	F	all
Johnny darter	F	(7)
Percichthyidae		
White bass	S	all
Percopsidae		
Trout perch	F	all
Salmonidae		
Rainbow trout	S	all
Brook trout	S, NC	**
Brown trout	S	all
Chinook salmon	S	migration (13)
Coho salmon	S	(14)
Atlantic salmon	NC	**

Table 10. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 2, inland warmwater locations and anadromous migratory routes, drowned river mouths, Lake Michigan, page 2 of 2 pages.

- * Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.
- ** Discussion of threatened fish and certain others should include seasonal occurrence on discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.
- (1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered; NC, not common.
- (2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.
- (3) Other activities represented by largemouth bass.
- (4) " " " " white sucker.
- (5) " " " " smallmouth bass.
- (6) " " " " alewife.
- (7) " " " " mottled sculpin.
- (8) " " " " spottail shiner.
- (9) " " " " northern pike.
- (10) " " " " channel catfish.
- (11) " " " " longnose gar.
- (12) " " " " yellow perch.
- (13) " " " " rainbow trout.
- (14) " " " " chinook salmon.

Table 11. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 9, inland warmwater locations, Kalamazoo River (Kalamazoo County), page 1 of 1 page.

important species or category	Rationale (1)	"Representative important species" for thermal component of discharge life form or activity to be evaluated (2)
<u>Periphyton</u>	F, N, CI	*
<u>Macrophyton</u>	F, N, CI	*
<u>Zooplankton</u>	F, CI	*
<u>Macroinvertebrates</u>	F, CI	*
<u>Fish</u>		
<u>Anilidae</u>		
Bowfin	CI, NC	**
<u>Catostomidae</u>		
White sucker	F, S	all
Spotted sucker	F	(3)
Quillback	F	(3)
Northern redbhorse	F, S	(3)
Creek chubsucker	F	(3)
<u>Centrarchidae</u>		
Smallmouth bass	S	all
Largemouth bass	S	all
Bluegill	S, NC	**
Longear sunfish	CI	(4)
Green sunfish	S	(4)
Pumpkinseed	S	(4)
Rock bass	S	(5)
Warmouth bass	S, NC	**
Black crappie	S, NC	**
<u>Cottidae</u>		
Mottled sculpin	F, NC	**
<u>Cyprinidae</u>		
Carp	PT, F, S	all
Goldfish	PT, F	all
Satinfin shiner	F	(7)
Spotfin shiner	F	(7)
Golden shiner	F	(7)
Common shiner	F	(7)
Creek chub	F	(7)
Hornyhead chub	F	(7)
Bluntnose minnow	F	all
<u>Esocidae</u>		
Northern pike	S	all
Mud pickerel	CI	(8)
<u>Ictaluridae</u>		
Channel catfish	S	all
Black bullhead	S	(9)
Brown bullhead	S	(9)
Yellow bullhead	S	(9)
Stonecat	CI	(9)
<u>Percidae</u>		
Walleye	S, NC	**
Johnny darter	F	all
Blackside darter	F	(6)
<u>Umbridae</u>		
Mudminnow	F	(7)

* Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.

(1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered.

(2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.

(3) Other activities represented by white sucker.
 (4) " " " " largemouth bass.
 (5) " " " " smallmouth bass.
 (6) " " " " Johnny darter.
 (7) " " " " bluntnose minnow.
 (8) " " " " northern pike.
 (9) " " " " channel catfish.

Table 12. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 9, inland warmwater locations, Grand River, Lansing.
page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
Periphyton	F, N, CI	*
Macrophyton	F, N, CI	*
Zooplankton	F, CI	*
Macroinvertebrates	F, CI	*
Fish		
<u>Catostomidae</u>		
White sucker	F, S	all
Hog sucker	F	(3)
Sooted sucker	F	(3)
Northern redborse	F, S	(3)
<u>Centrarchidae</u>		
Smallmouth bass	S	all
Largemouth bass	S	all
Bluegill	S, NC	**
Pumpkinseed	S	(4)
Black crappie	S, NC	**
<u>Cyprinidae</u>		
Carp	PT, S, F	all
Common shiner	F	all
<u>Esocidae</u>		
Northern pike	S	all
<u>Ictaluridae</u>		
Black bullhead	S	(4)
<u>Lepisosteidae</u>		
Longnose gar	CI	all

- * Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.
 - ** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.
- (1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered; NC, not common.
- (2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.
- (3) Other activities represented by white sucker.
- (4) " " " " " largemouth bass.

Table 13. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 9, inland warmwater locations, Tittabawassee River, page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
<u>Periphyton</u>	F, N, CI	*
<u>Macrophyton</u>	F, N, CI	*
<u>Zooplankton</u>	F, CI	*
<u>Macroinvertebrates</u>	F, CI	*
<u>Fish</u>		
<u>Catostomidae</u>		all
White sucker	F, S	(3)
Northern redbhorse	F, S	
<u>Centrarchidae</u>		all
Smallmouth bass	S	(4)
Rock bass	S	(4)
Black crappie	S	(4)
White crappie	S	(4)
Bluegill	S	(4)
Pumpkinseed	S	(4)
Longear sunfish	CI	(4)
<u>Clupeidae</u>		all
Gizzard shad	F	(5)
Alewife	F	
<u>Cyprinidae</u>		all
Carp	PT, F, S	all
Common shiner	F	
<u>Esocidae</u>		all
Northern pike	S	
<u>Ictaluridae</u>		all
Channel catfish	S	(6)
Black bullhead	S	(6)
Stonecat	CI, F	(6)

- * Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

- (1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered.
- (2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.
- (3) Other activities represented by white sucker.
- (4) " " " " smallmouth bass.
- (5) " " " " gizzard shad.
- (6) " " " " channel catfish.

Table 14. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 9, inland warmwater locations and anadromous migratory routes, Black River (St. Clair Co.), page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
<u>Periphyton</u>	F, N, CI	*
<u>Macrophyton</u>	F, N, CI	*
<u>Zooplankton</u>	F, CI	*
<u>Macroinvertebrates</u>	F, CI	*
<u>Fish</u>		
<u>Catostomidae</u>		
White sucker	F, S	all
Longnose sucker	F	(3)
Hog sucker	F	(3)
<u>Centrarchidae</u>		
Smallmouth bass	S	(4)
Rock bass	S	all
<u>Cottidae</u>		
Mottled sculpin	F	all
<u>Cyprinidae</u>		
Carp	PT, F, S	all
Creek chub	F	all
Common shiner	F	(5)
<u>Ictaluridae</u>		
Stonecat	F, CI	(6)
<u>Percidae</u>		
Johnny darter	F	all
Blackside darter	F	(7)
Greenside darter	F	(7)
<u>Salmonidae</u>		
Rainbow trout	S, NC	**
Chinook salmon	S, NC	**

* Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

** Discussion of threatened fish and certain others should include seasonal occurrence in discharge vicinity and adjacent waterbody segment plus any observations on behavior, mortality, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.

(1) C, commercial; CI, community integrity; F, forage; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered; NC, not common.

(2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, feeding, sexual maturity, size, disease and other pertinent information. Thermal tolerance data should be part of the discussion.

(3) Other activities represented by white sucker.

(4) " " " " rock bass.

(5) " " " " creek chub.

(6) " " " " mottled sculpin.

(7) " " " " Johnny darter.

Table 15. Michigan biota to be considered in demonstration to satisfy Section 316, P.L. 92-500, Zone 9, inland warmwater locations and anadromous migratory routes, Grand River at Grand Rapids, page 1 of 1 page.

Important species or category	Rationale (1)	"Representative important species" for thermal component of discharge Life form or activity to be evaluated (2)
<u>Periphyton</u>	F, N, CI	*
<u>Macrophyton</u>	F, N, CI	*
<u>Zooplankton</u>	F, CI	*
<u>Macroinvertebrates</u>	F, CI	*
<u>Fish</u>		
<u>Amiidae</u>		
Bowfin	CI	(3)
<u>Catostomidae</u>		
White sucker	F, S	all
Hog sucker	F	(4)
Quillback	F, CI	(4)
Northern redborse	F, S	(4)
<u>Centrarchidae</u>		
Smallmouth bass	S	all
Largemouth bass	S	all
Bluegill	S	(3)
Pumpkinseed	S	(3)
Rock bass	S	(5)
Black crappie	S	(3)
<u>Clupeidae</u>		
Gizzard shad	F	(6)
Alewife	F	all
<u>Cyprinidae</u>		
Carp	PT, S, F	all
Goldfish	PT, S, F	all
<u>Esocidae</u>		
Northern pike	S	all
<u>Gadidae</u>		
Burbot	F, S, CI	all
<u>Ictaluridae</u>		
Channel catfish	S	(5)
<u>Leptosteidae</u>		
Longnose gar	CI	all
<u>Percidae</u>		
Walleye	S	all
Yellow perch	F, S	(7)
<u>Salmonidae</u>		
Rainbow trout	S	all
Brown trout	S	(8)
Coho salmon	S	(9)
Chinook salmon	S	all

* Discussion of the lower trophic levels should include community dynamics by season and effects of thermal components of the discharge on life history processes, including enhancement, inhibition, preclusion, etc. on important components of the community. Response of the macroinvertebrates should include community structure analysis and diversity computations based on information theory. Thermal tolerance data should be part of the discussion.

(1) C, commercial; CI, community integrity; F, forane; N, nuisance, population not to be enhanced; PT, pollution tolerant, population not to be enhanced; S, sport; T, threatened or endangered.

(2) Unless otherwise specified "all" means the applicable descriptors of the following: eggs, larvae, fry, yearlings, adults, spawning, feeding, migration, reproduction, growth, metabolism and other activities which are or may be necessary to maintain population integrity.

(3) Other activities represented by largemouth bass.
 (4) " " " " " white sucker.
 (5) " " " " " smallmouth bass.
 (6) " " " " " alewife.
 (7) " " " " " walleye.
 (8) " " " " " rainbow trout.
 (9) " " " " " chinook salmon.